WETLAND AND RIPARIAN RESOURCE ASSESSMENT OF THE GALLATIN VALLEY AND BOZEMAN CREEK WATERSHED, GALLATIN COUNTY, MONTANA

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For
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This project would not have been possible without the support and assistance of Lynda Saul with the Montana Department of Environmental Quality. A lot of other people contributed to the project, but four individuals were instrumental in its success. David Moody (GISPix) processed color infrared aerial photographs taken for the project into high-resolution digital images. These images formed the backbone of the mapping efforts. The care and quality with which David completed the work resulted in high quality images that have been in demand ever since they were created. Corey Baker, a graduate student at Montana State University, was invaluable for his work in analyzing the color infrared imagery and building the GIS database showing the current locations of wetland and riparian areas. This aspect of the project was a huge task and critically important. Corey spent many months analyzing the imagery and mapping the locations of wetland and riparian features. Importantly, he did it with patience, self-discipline, and concern with the quality of the final product. Curtis Kruer, a consulting wetland ecologist, completed the difficult task of constructing a GIS layer to show the historical extent of wetland and riparian areas. This work was also important component of the project. Curtis accepted and completed this challenge with very little guidance, since it was unclear how best to proceed. Finally, Valerie Harms researched the history of the Gallatin Valley. She had the difficult task of trying to document how human activities have impacted wetland and riparian resources. The historical information she collected filled the gaps between the maps created by Corey and Curtis, providing a glimpse into how changes have occurred.

Rick Ladzinski, with the Bozeman Watershed Council, assisted with the inventory of wetland and riparian features in the upper Bozeman Creek Watershed. Rick, along with Valerie Harms, also contributed many hours of fieldwork to ground-truthing wetland and riparian areas that were inventoried. Karin Jennings, Joe Gutkoski, Linda Wallace, and Tammy Crone also assisted with the ground-truthing. They graciously volunteered their time and expertise to this important task. Finally, the following people assisted by attending steering committee meetings, providing information, and/or providing interviews for the project:

Dean Adams (Oral interview)
Diane Alexander (Bozeman Chronicle Research)
Katie Alvin (Gallatin Cons. Dist.)
Duane Anderson (NRIS)
Tim Crawford (flood photographs)
Thedis Crowe (Indian history)
Debbie Deagan (GVLT)
Janet Ellis (Montana Audubon)
Doug Harrison (NRCS)
Pete Husby (NRCS)
Beth Keating (Sacajawea Audubon)
Radell Key (Ground-truthing)
Susan Lenard (Montana Audubon)
Ted Lange (GVLT)
Jim Maden (GVLT)
Clayton Marlow (MSU Extension)
Dale Martin (MSU Historian)
Pat Mohler (Pioneer Museum Research)
Kay Moore (Oral interview)
Greg Munther (U.S. Forest Service)
Tom Pick (NRCS)
Tony Rolfes (NRCS)
Volney Steele (Historical Information)
Derek Strahn (Railroad History)
Charles Van Hook (Lewis and Clark)
Dave Wessell (Oral interview)
Marcia Youngman (Oral interview)
Yolonda Youngs (MSU student)

PURPOSE AND BACKGROUND

Importance of Wetlands

In terms of human development and land use, wetlands have often been viewed as wastelands or areas with limited development potential. Historically wetlands have been drained or filled-in so that the land area could be "used for beneficial human purposes". This view of wetlands does not reflect the values and benefits associated with them. It is estimated that wetlands covered 220 million acres of the lower 48 states prior to European settlement (Brown & Lant, 1999). By the mid-1980s wetland areas had been reduced to 103 million acres, representing a loss of about 54% of the nations wetland areas. Prior to the 1980's wetlands were mainly converted to agricultural lands. Since the 1980's it is estimated that over 80% of wetland losses are due to non-agricultural activities (Brown & Lant, 1999). Wetlands serve a number of important functions and provide benefits to humans and wildlife. The following benefits of wetlands are often overlooked:

- ✓ **Wildlife habitat** – Many species are dependent upon wetlands for all or a portion of their life cycle. Wetlands provide habitat for fish, birds, mammals, reptiles, amphibians, and invertebrates.

- ✓ **Erosion control** –Wetlands support vegetation that acts as a flood buffer and reduces stream bank erosion during flooding events.

- ✓ **Floodwater storage** –Wetlands store water during flooding events and then slowly release the water as flooding subsides. This can significantly reduce peak flood flows and resulting flood damage downstream.

- ✓ **Ground water recharge** –Wetlands store surface water, which then infiltrates into the ground, providing recharge to aquifers. This ground water recharge in turn is slowly released back to adjacent surface water bodies, such as streams, providing water during low flow periods (base flow).

- ✓ **Water purification** –Wetlands improve water quality by filtering polluted runoff from cities and agricultural lands. They trap sediments, utilize excess nutrients present in runoff, and breakdown many waterborne contaminants. Constructed wetlands are being used to treat contaminated waters from mines, sewer systems, and urban stormwater runoff.

- ✓ **Recreation & Economic Benefits** –Wetlands are often visited for recreational purposes such as hiking, bird watching, wildlife photography, and hunting. These activities can translate into dollars spent at local businesses, adding to the economy.

- ✓ **Education –** Wetlands make excellent and inexpensive outdoor laboratories for students of all ages. For example, the Cherry River recreation site located on the north side of Bozeman, Montana is visited by hundreds of school children each year. The students get to see numerous plants and animals, and the cost to local schools is minor, other than the transportation.

Research has been conducted to try and determine what the economic benefits of wetlands are. The monetary value of the ecological functions that various ecosystems provide, relative to what it would cost for humans to engineer facilities to perform the functions was evaluated by Mitsch and Gosselink (2000). Table 1 shows the results of their analysis. Estuaries and wetlands had much higher values than other ecosystems.

Table 1
Functional Ecological Value of Wetlands and other Ecosystems

Ecosystem Type	Unit Value ($/ha/year)
Estuaries	$22,832
Wetlands	$14,785
Lakes and Rivers	$8,498
Forests	$969
Grasslands	$232

From Mitsch & Gosselink (2000)

Importance of Riparian Areas

For purposes of this report, riparian areas are defined as the areas in and adjacent to rivers and streams where woody vegetation (trees and shrubs) is present. Like wetlands, riparian areas serve a number of important functions and provide benefits to humans and wildlife. However, rather than being viewed as wastelands, riparian areas are often targeted for residential and commercial development for aesthetic reasons. While low levels of development within riparian areas may not cause significant problems, widespread development in and adjacent to riparian corridors can degrade the ecological function of the area and present public health and safety problems. These safety problems are mainly due to the natural flooding processes that occur in riparian habitat. As an example, Figure 1 shows a house that fell into the West Gallatin River during a flooding event in June of 1986. Note the proximity of the house to the river and the riparian vegetation around the home site.

Figure 1. House destroyed by flooding of the West Gallatin River in June 1986 (Photo courtesy of Scott Gillilan).

The following benefits of riparian areas often overlooked:

- ✓ **Erosion Control –**Roots of trees, shrubs, and grasses hold soil in place along the banks of rivers and streams, reducing the potential for bank erosion, and deposition of sediment in streams and rivers.

- ✓ **Flood Control –**Vegetation along the banks of rivers and streams and within floodplains slows the movement of floodwaters. The vegetation also aids in dispersing the floodwaters and allowing some of the water to soak into the floodplain adjacent to the river or stream.

- ✓ **Wildlife Habitat** –Riparian areas provide important wildlife habitat. Trees and other vegetation provide cover and shelter for wildlife. The riparian areas also serve as migration corridors for wildlife. Roots from trees and shrubs along the banks of rivers and streams often form “holes” that provide shelter for fish.

- ✓ **Temperature Control –**Trees and shrubs adjacent to rivers and streams provide shade, which reduced water temperatures. High water temperatures harm fish and other aquatic life.

- ✓ **Recreation & Economic benefits** –Like wetlands, riparian areas are often visited for recreational purposes such as hiking, bird watching, wildlife photography, fishing, and hunting. These activities can translate into dollars spent at local businesses, adding to the local economy.

- ✓ **Filtering of Runoff** –Riparian vegetation in floodplains and along rivers and streams act as natural filters to remove sediment and other contaminants from stormwater runoff from adjacent land surfaces.

Funding

This project was partially funded by the Montana Department of Environmental Quality (DEQ) Wetland Protection Program through DEQ contract # 202014. The DEQ grant funding of $53,989 originated through the U. S. Environmental Protection Agency (EPA) Region VIII Ecosystems Protection Program. In addition, cash and in-kind services totaling more than $40,122 were contributed as match. The Gallatin Local Water Quality District administered the project and provided matching funds. The agencies and organizations listed in Table 2 also provided matching funds.

Table 2
Matching Funds Provided by Agencies and Organizations

Agency or Organization	In-Kind Match	Cash Match
Bozeman Watershed Council	$2,300	
City of Bozeman Planning Department		$5,000
Gallatin County Disaster and Emergency Services		$5,000
Gallatin County GIS Department		$7,583
Gallatin County Planning Board		$2,000
Gallatin Local Water Quality District	$16,018	$1,552
Volunteers (calc. At $8/hour * 83.5 hours)	$668	
Totals	$18,986	$21,135

Project Area Description
The project area is located within Gallatin County, in southwestern Montana. With the exception of the western margin, the project area is located within the boundary of the Gallatin Local Water Quality District (GLWQD). Figure 2 shows the location of Gallatin County and the GLWQD within Montana.

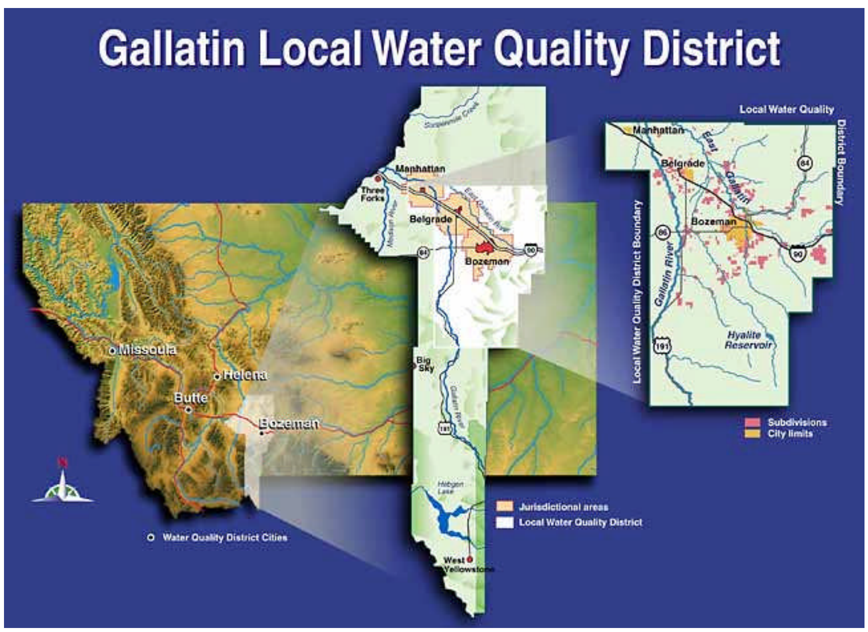

Figure 2. Location of Gallatin County and Gallatin Local Water Quality District in Montana.

The project area and project area boundary are shown in Figure 3. The area covers approximately 520 square miles, centered over the Gallatin Valley. The project area boundary generally follows the margins of the floor of the Gallatin Valley, with the exception of including the upper Bozeman Creek watershed. This area was included as a cooperative effort to assist the Bozeman Watershed Council with a resource assessment of the Bozeman Creek watershed, which included an inventory of wetlands.

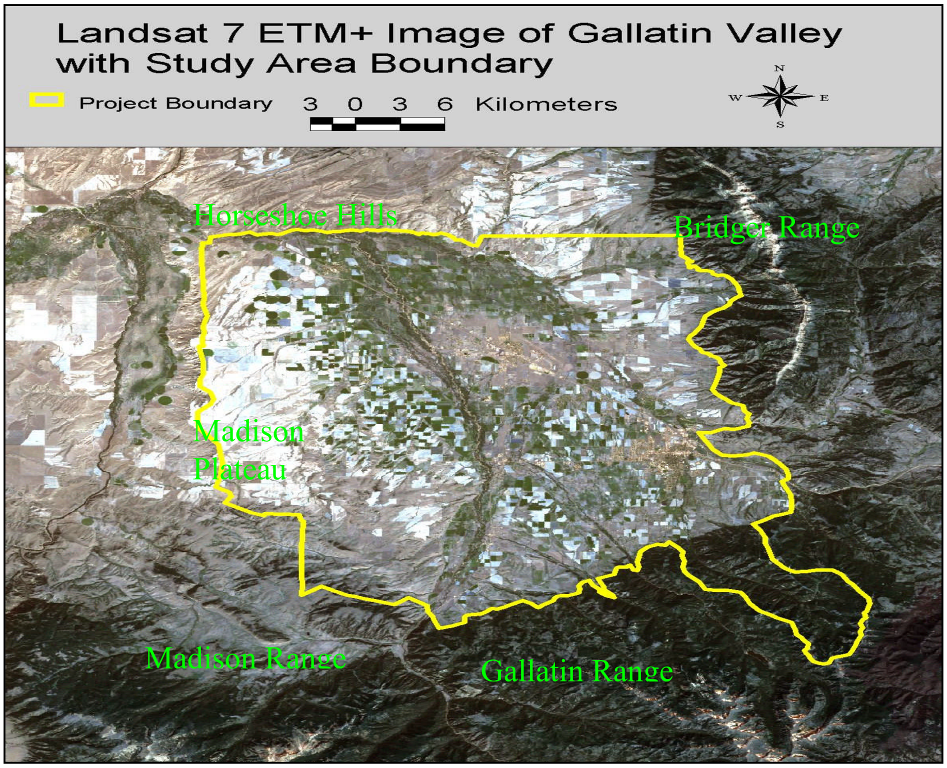

Figure 3. Oblique Landsat satellite view of the Gallatin Valley showing the project area and the major landforms surrounding the project area.

Hydrogeologic Setting

The Gallatin Valley is bounded by the Gallatin Range to the south, the Bridger Range to the east, the Horseshoe Hills to the north, the Madison Plateau to the west, and the Madison Range to the southwest (Figure 3). Elevations in the valley range from about 4,800 to 4,100 feet above mean sea level. The climate in the valley is semi-arid with annual precipitation ranging from about 12 to 18 inches. The surrounding mountains receive significantly more precipitation, primarily as snow. The Gallatin, Madison, and Bridger ranges provide most of the runoff that supports streams and rivers in the valley. These mountains are also the main source of ground water recharge for the valley aquifer system (Hackett 1960, Slagle 1995).

The Gallatin Valley is a large intermontane valley, which occupies the eastern half of a much larger structural basin known as the Three Forks structural basin (Hackett, 1960). The spatial distribution of wetland and riparian features in the valley appears to be heavily influenced by the tectonic setting and resulting bedrock structure of the area. As a result of the bedrock structure, the floor of the valley slopes downward from the southeast towards the northwest. Figure 4 shows an oblique high-altitude aerial view of the valley created by overlaying a mosaic of color infrared imagery over digital elevation model (DEM) data. The general tilt of the valley floor from southeast (Bozeman Area) towards the northwest (Logan area) can be visualized in the view. Note also the striking linear boundary between the valley floor near Manhattan and the bedrock structure of the Horseshoe Hills to the north, seen in the lower foreground of Figure 4. This feature suggests the presence of a fault with the valley floor dropped down on the south side of the fault.

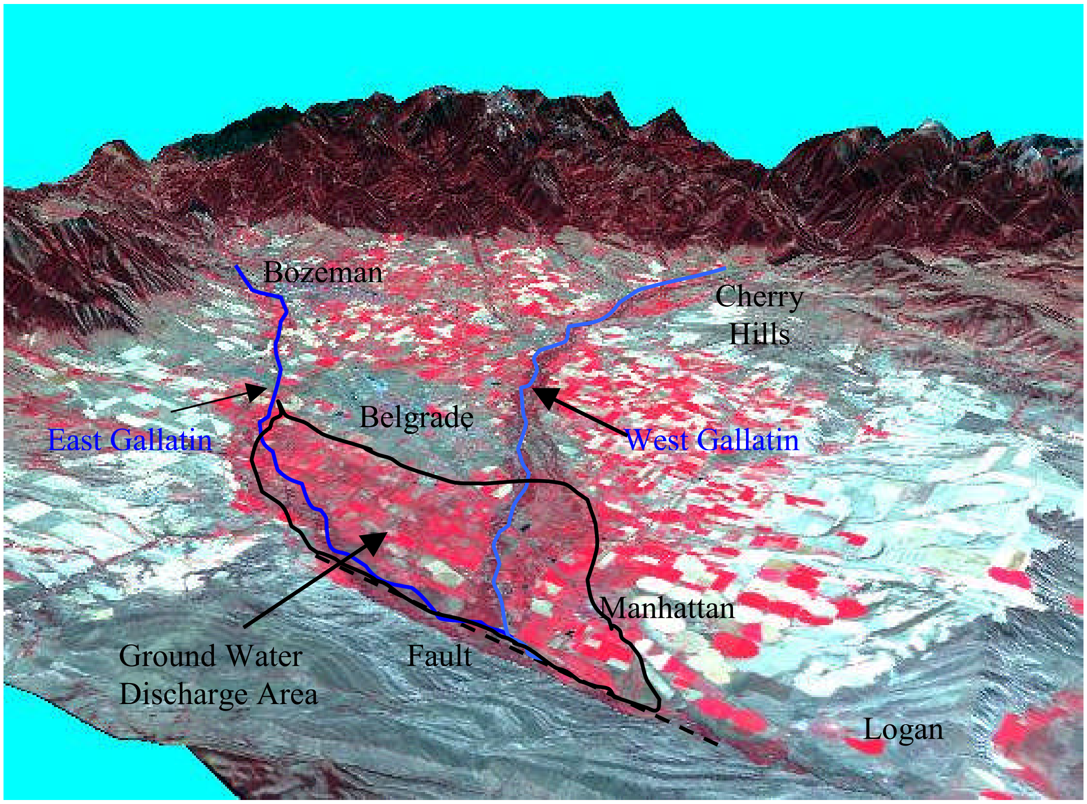

Figure 4. Oblique high altitude view of the Gallatin Valley looking towards the Southeast, from over the Horseshoe Hills. The color infrared imagery created for the project is draped over a digital elevation model to produce the view.

The view in Figure 4 shows that the West Gallatin and East Gallatin rivers, and all of their tributary streams, flow from their headwaters out into the valley towards the northwest corner, merging near the town of Logan. The West Gallatin River initially flows due north, blocked from flowing towards the northwest by the bedrock foothills of the Madison Range (Cherry Hills). North of Belgrade and Manhattan the East Gallatin River flows up against the northern edge of the valley, following the fault boundary exposing the bedrock of the Horseshoe Hills. The behavior of the river and the linear nature of the bedrock outcrops in this area suggest that the valley may still be tectonically active.

Ground-water flow patterns, as mapped by Slagle (1995), mimic the surface water flow patterns, with ground water flowing from the east, southeast, and south towards the northwest. Where ground water merges in the northern portion of the valley a large ground water discharge area is present. This discharge area is inferred from the presence of shallow ground water, the appearance of numerous spring fed creeks, and a concentration of darker shades of red on the CIR imagery as shown in the center foreground in Figure 4.

STEERING COMMITTEE

A steering committee was formed to assist with completion of the project. The primary purpose of the steering committee was to provide input on how to develop the CIR imagery, map wetland and riparian features, construct the GIS database, and compile the historical information. This committee met four times between December 2001 and April 2003. A group email list was created to contact steering committee members and others interested in the project. The following individuals served on the steering committee:

Table 3
Project Steering Committee Members

Name	Affiliation
Katie Alvin	Gallatin Conservation District
Allen Armstrong	Gallatin County GIS Department
Alan English	Gallatin Local Water Quality District
James Goehrung	City of Bozeman and Bozeman Watershed Council
Beth Kaeting	Sacajawea Audubon
Rick Ladzinski	Bozeman Watershed Council
Jim Madden	Gallatin Valley Land Trust
Duncan Patten	MSU Riparian Ecologist
Judy Sandford	City of Bozeman Planning Department
Lanette Windemaker	Gallatin County Planning Department

LIMITATIONS

Inventory vs. Delineation

The land areas identified in this report as **wetlands** do not represent **delineated wetlands** for regulatory purposes. The wetland areas are referred to as **inventoried**, and were located using a combination of color infrared (CIR) aerial imagery, ground-truthing, and existing information. The areas mapped are considered to be ecological wetlands rather than jurisdictional wetlands as defined by the Army Corp of Engineers. Inventoried areas represent land areas where the preponderance of information indicates wetlands are probably present, but these areas have not been delineated to verify the presence of jurisdictional wetlands.

The areas identified as **riparian/wetlands mixed** were primarily inventoried based on visible indications of color and texture on the CIR imagery. The focus was on woody riparian trees and shrubs that were easily identified on the CIR imagery. Wetlands are also present in many areas of visible woody riparian vegetation. Since these wetlands could not be viewed through the riparian canopy, but were known to be present, the inventoried areas are referred to as **riparian/wetland mixed**. The minimum mapping unit size for both types of inventoried areas is approximately ½ acre.

A conservative approach was used to inventory the wetland areas, meaning some areas inventoried as wetlands may not be actual wetlands. Due to the limitations of the imagery and the methods used, there is also the possibility that wetland areas were missed.

The intent of this project was to provide a reasonable spatial representation of the locations of wetland and riparian areas to help guide the need for more detailed site investigations.

CIR Imagery and GIS Database

The color infrared (CIR) imagery used as the primary reference for this project was developed from aerial photographs taken on September 9, 2001. The photos were processed into digital orthophoto quadrangle (DOQ) maps. These maps were used as an image layer to create a Geographic Information System (GIS) database. While project work was conducted between 2001 and 2004, the inventory of wetlands and riparian areas is considered current as of the aerial photography date in 2001. The GIS database developed for the project is primarily a spatial database focused on the geographic location of the inventoried wetland and riparian areas. Detailed inspections of all of the inventoried areas (approximately 900) were not completed. However, over 240 sites were field checked to help assure the accuracy of the computer mapping. The attributes associated with the inventoried areas in the GIS database are limited, but do include other useful information. The structure of the GIS database allows for adding more fields and information in the future if needed.

Historical Mapping

The historical extent of wetlands and riparian areas was determined using a combination of historical aerial photographs, historical research, and existing spatial databases with attributes associated with wetlands and riparian areas. Due to the limitations of these resources the historical extent of wetlands and riparian areas could not be determined separately. The areas mapped represent the "*maximum potential historical extent of aquatic resources*." This layer includes potential historical wetlands and riparian areas, and surface water features.

PROJECT GOALS, OBJECTIVES, AND TASKS

When the project proposal was written the focus was on assessing the spatial extent of wetland resources. Prior to starting the project it was decided that riparian features should be included. For this reason, the project goals and objectives as presented below do not specifically mention riparian resources. Seventeen specific tasks were associated with the original project goals and objectives. For reference, these tasks are provided in Attachment A. Due to unforeseen problems, some of the objectives could not be completed as originally proposed. Comments on the success of the objectives are provided in italics below.

Overview and Assessment of Goals and Objectives

I. GIS Database Goal: Establish a GIS database, containing historical and current spatial data on wetlands to aid in management and interpretation of wetlands data, and provide wetlands data to all interested government agencies, local developers, local landowners, and the public.

- **Objective**: Construct GIS coverage to show the current status of wetlands within the Gallatin Valley and Bozeman Creek watershed based on 2001/2002 field mapping. C*ompleted successfully, based on 2001 aerial photography*.

- **Objective:** Incorporate historical wetlands spatial data into the Gallatin County GIS system and create map coverage showing the historical extent of wetlands within the Gallatin Valley and Bozeman Creek Watershed. C*ompleted successfully*.

- **Objective**: Incorporate the National Wetlands Inventory (NWI) mapping data into the Gallatin County GIS system. C*ompleted successfully*.

II. Wetland Preservation and Restoration Prioritization Goal: Identify and prioritize wetland areas within the Gallatin Valley and Bozeman Creek watershed that are threatened and/or in need of restoration, including analysis of growth patterns and changes in land use practices (including irrigation) that threaten wetland areas based on the GIS database.

- **Objective:** Develop a prioritized list of wetland areas within the Gallatin Valley and Bozeman Creek watershed that are in need of preservation and restoration. C*ompleted successfully, but only in regional perspective. With over 900 sites identified within a 520 square mile area, detailed analysis and prioritization was not practical within the scope and funding of the project.*

- **Objective**: Document the extent of wetland areas that have been lost or impaired, and the reason(s) for the losses or impairments. C*ompleted successfully, the extent of the loses were documented using the GIS database, the reasons were documented to the extent possible and included as attributes in the GIS database*.

III. Education and Outreach Goal: Through outreach aimed at local government agencies including Planning Departments, local developers, landowners, and elected officials, increase public awareness of the importance of wetlands, the current status of wetlands in the Gallatin Valley and Bozeman Creek watershed, and the impacts development has had on wetlands.

- **Objective:** Provide public access to the results of the study via the Internet. C*ompleted successfully, but considered an ongoing effort. This report will be available as a PDF format document on the Internet. The CIR imagery has been provided to many interested parties, is available on the USGS National Map site, and was provided to NRIS. The GIS database can't be placed on the Districts web site at this time, but has been provided to NRIS for placement on the NRIS website*.

- **Objective:** Conduct education and outreach activities to present the results of the wetlands study to Federal, State, and local agencies involved with land use planning and resource management. C*ompleted successfully and considered ongoing*.

- **Objective:** Conduct education and outreach activities aimed at local developers, realtors, landowners, trade organizations, and civic groups. C*ompleted successfully and considered ongoing*.

DEVELOPMENT OF ORTHORECTIFIED CIR IMAGERY

Fundamentals of Using CIR Aerial Photography to Map Wetlands
The broad spectrum of electromagnetic energy emitted by the sun ranges from short wavelength gamma rays to long wavelength radio waves. This spectrum has been categorized into energy types, such as ultraviolet (UV) radiation, infrared radiation (IR or heat), and visible light (Figure 5). Within the visible spectrum most plants reflect green light in the visible range, which is detected by the human eye. Plants that are actively growing (undergoing photosynthesis) also reflect a significant amount of infrared energy, which is not visible to the human eye. In fact, plants reflect enough infrared energy that CIR photographs can be used to detect differences between different plant communities that are not visible to the human eye. Similar to standard color film, CIR film is sensitive to the green and red wavelengths of light that reflect from objects on the earth. Additionally, the CIR film is able to detect the infrared light reflected by objects.

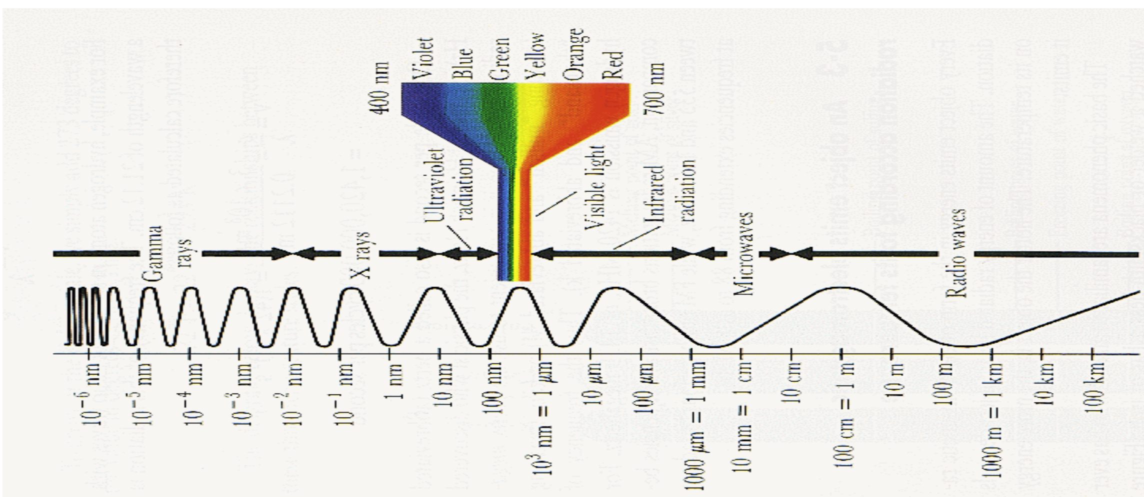

Figure 5. Energy types and wavelengths in the electromagnetic spectrum.
Source: Blair, B., Hopkins Ultraviolet Telescope
(http://praxis.pha.jhu.edu/science/emspec.html)

When sunlight strikes the leaf of an actively growing plant a large amount of infrared light is reflected. The sensitivity of the CIR film to the infrared light allows for recording the areas of high infrared reflectance associated with the actively growing vegetation. As a result, healthy, photosynthesizing plant communities appear bright red on CIR film instead of the visible green color displayed on standard color film. More accurately, the film used is referred to as *False Color Infrared* film. This is due to the fact that while the film is sensitive to light energy in the visible spectrum, when exposed the colors visible on the photographs are not true colors. For example objects that appear blue to the human eye, such as water, show up as black on the CIR photograph. Objects that appear red to the human eye tend to show up on the CIR photograph as green.

Areas covered by vegetation that is dead or dying tend to show up as shades of white and grey. This is due to the way that visible light and infrared radiation is reflected from the plants. Figure 6 shows the difference in reflectance from an actively growing leaf and a dying leaf. The first illustration in this figure shows the green and infrared light being reflected from a mature leaf structure as the blue and red light is absorbed. Since the infrared light is invisible to the human eye, the leaves display a prominent green color. In the second illustration, this same leaf has completed its growing cycle and the spongy mesophyll layer has been depleted of moisture and intracellular air space. The spectral result of this change is that blue and red light are no longer absorbed by the leaf and are reflected along with green and infrared to give the leaf a brighter and more washed out color.

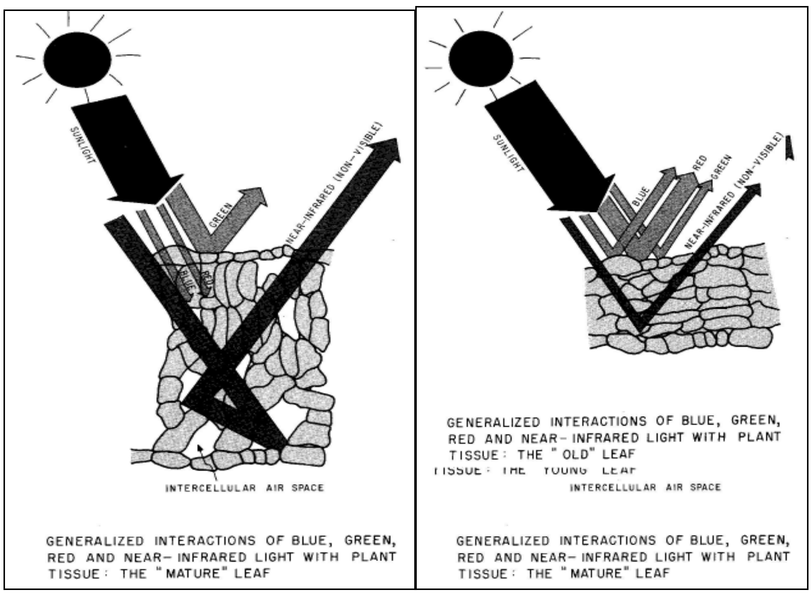

Figure 6. Comparison of visible and infrared light reflection from actively growing verses dying leaf structures (Samson, S.A. 2000)

CIR imagery was used in this wetland identification project to capitalize on the spectral differences occurring in local plant communities during the month of September. Similar to most of the inter-mountain west, warm temperatures, low humidity, and low precipitation dominates the August through September weather in south-central Montana. The lack of moisture during this period promotes plant senescence (die off) in upland plant communities by September. However, the prevalence of water in wetland areas enables many of these plant species to continue growing until colder temperatures limit plant function.

Color Infrared Aerial Photography of the Gallatin Valley

The color infrared (CIR) aerial photography of the Gallatin Valley was taken on September 9, 2001. The flight was timed so that it was between the end of the growing season and before the first killing frost for most upland plants. By September, most of the plants that were still actively photosynthesizing were either being irrigated, growing in sub-irrigated areas (shallow ground water), or growing in wetland and riparian areas.

Montana Aerial Photography out of Missoula, Montana conducted the flight. The photos were taken from about 12,000 feet above ground level. The combination of flight altitude, land-surface elevation, and photo frame size (9-inch by 9-inch), resulted in a photo scale of about 1:24,000. To cover the project area 14 flight lines were flown and 252 photographs were taken. The spacing of the flight lines and photo frames along the flight lines were set so that there was 60% overlap between photos along a flight line and 30% overlap from one flight line to the next. This allowed for viewing the photographs in three dimensions using a stereoscope. The flight line map and a complete set of color prints for the flight were obtained and are available for viewing at the Gallatin Local Water Quality District office in Bozeman, Montana.

Transforming CIR Aerial Photographs Into Digital Photographs

Once the aerial photographs were obtained they were transformed into digital photographs that could ultimately be processed into digital orthophoto quadrangle (DOQ) maps (explained below). Steps were taken to preserve as much detail as possible from the original photographs so that the aerial photography could be used to identify wetland and riparian areas on the computer screen using ArcView™ GIS software. The film from the aerial photography flight was developed as a color positive and shipped to Michael Baker Jr., Inc., in Beaver, Pennsylvania to be scanned. Scanning the color positive film, rather than the contact prints, helped to preserve the details of the images.

Michael Baker Jr., Inc. used a high-resolution photogrametric scanner to scan each photo frame. This also aided in preservation of the original image quality. Each photo frame was scanned at a setting of 907 dots per inch (dpi), which is equal to an image pixel size of 28 microns. The images were "dodged" when scanned to help reduce the effects of shadows and bright spots on the photographs. Each scan file was then saved as a TIFF format digital image with the file name matching the flight line number and photo number. For example file 01-12 was the file name assigned to photo number 12 on flight line number 1. Due to the high dpi setting used to scan the frames, the resulting file size for each TIFF image was 209 megabites. The TIFF files were saved on both compact discs (CD) and digital video discs (DVD). To store the data it took 85 CDs and 12 DVDs.

Orthorectification of Digital CIR Photographs and Creation of CIR DOQs

The scanned TIFF images were processed and compiled into DOQ maps that covered the same areas as published U.S. Geological Survey 7.5-minute quadrangle maps. The file names used for the CIR DOQs matched the 7.5-minute quadrangle names. The goal was to create digital images that could be used as base maps in ArcView™ GIS software. The process of converting the scanned TIFF images is referred to as orthorectification, and required specialized software and skills. David Moody, with GISPix in Bozeman, Montana, was hired to complete the orthorectification, and provided the following details on how the aerial photographs were processed.

The software used to process the digital CIR photographs was PCI Geomatics^{TM}. The type of digital photogrammetry used to orthorectify the imagery is referred to as aero triangulation. The software uses the principles of triangulation to correct the photography in the x and y direction and incorporates the use of a digital elevation model (DEM) for the vertical (z) direction. The first step in the aero triangulation was to create an interior orientation by registering the fiducial marks (corner marks) of the aerial photographs. At the start of the project a camera calibration report (a very accurate description of the different types of distortion associated with the camera used to take the pictures) was entered into the system. The computer then used the measurements taken from the fiducial marks and computed them against the camera calibration report to create the "interior orientation" of the block model. For each TIFF image an interior orientation was calibrated.

The majority of time spent orthorectifying the photographs was spent obtaining ground control and tie points used to calculate the exterior orientation of the model. The ground control came entirely from points on 1995 black and white U.S. Geological Survey DOQs. The horizontal accuracy of these DOQs followed the National Map Accuracy Specifications that 90% of the points on image are within 40 feet of their true position. A total of 1082 ground control points were used for the project area, providing an even distribution of control throughout the project area. The root mean square value (RMS) for the project area was**: X-1.27 meters and for the Y-1.28 meters**. The highest RMS value for a ground control point accepted in the model was 5 meters, (in a few locations where there was a large discrepancy in accuracy between overlapping DOQs).

The other labor-intensive step was to obtain tie points between the images. A total of 1075 tie points were selected for the project area. The tie points help the computer recognize where the aerial photographs overlap and provide another point of reference by the software. The RMS score for the tie points was as follows: **X-.10 meters, Y-.07 meters**. After all the ground control points and tie points were established the software was able to generate orthophotos from each of the raw TIFF images.

The orthogeneration process created a single image (orthophoto) at a time, representing a subsetted area of each individual scanned image. The image created was a subset of the entire scanned photo so as to use only the most accurate portion of each aerial photograph (which is a towards the center) and so as not to include the periphery features, such as fiducial marks in the scanned image. It was possible to subset considerably as there was an average of 60% endlap and 30% sidelap for each photograph.

For vertical control 30-meter DEM data obtained from the USGS National Elevation Database was used in the orthorectification software. The DEM data were used by the processing software to adjust the horizontal position geometrically for topographic displacement. As a quality control measure for the project, each individual image created was swiped with the 1995 USGS black and white DOQ coverage for the same area to examine for inconsistencies in the images. The most common source of error came from points that were sharing overlapping positions on DOQs.

After the individual orthophotos were created it was necessary to mosaic the images to make the final DOQs, which are mosaics of individual orthophotos. Mosaics were created that would cover the same area as the corresponding USGS 7.5-minute quadrangles. This process was completed using the PCI Geomatics™ software, which performed the difficult task of choosing the best possible cut-lines in the overlapping images to most effectively produce a seamless appearance on the final mosaic. The computer selected the portions in overlapping photos that had the highest brightness value, which helped to eliminate shadows and dark areas. The mosaics created were larger than the desired quadrangle and it was necessary to subset (trim) the mosaics to match the 7.5-minute quadrangle boundaries. The images were cut to the NAD 83 tics on the 7.5-minute quadrangles to create the final DOQ maps.

The final products were 19 complete or partial CIR DOQs for the project area with a pixel resolution of 0.66 meters (2.2 feet). To allow for viewing the entire project area on the computer screen at one time, all of the images were also mosaiced into single images at resolutions of 5 and 10 meters. These files were much smaller and easier to handle. All of the CIR DOQ images were saved on DVDs. These DVDs have been provided to the Montana Natural Resources Information Center (NRIS), the USGS National Map project (http://nationalmap.gov), interested Gallatin County and City of Bozeman Departments, and a number of local consulting firms. They can also be obtained from the Gallatin Local Water Quality District. Table 4 lists the files available for the imagery.

Table 4
Color Infrared Digital Orthophoto Files

DVD #	USGS Quadrangle (file name)	File Size (MB)	Full Quad	NWI Maps
1	Anceney	940	Yes	Yes
1	Cherry Creek	35.6	No	No
1	Logan	228	No	No
1	Madison Plateau	528	No	Yes
1	Manhattan	945	Yes	Yes
1	Manhattan Southwest	517	No	Yes
1	Nixon Gulch	442	No	Yes
2	Ruby Mountain	938	Yes	No
2	Gallatin Gateway	949	Yes	Yes
2	Bozeman Hot Springs	949	Yes	Yes
2	Belgrade	938	Yes	Yes
2	Horseshoe Creek	411	No	Yes
3	Flathead Pass	457	No	No
3	Miser Creek	928	Yes	Yes
3	Bozeman	935	Yes	Yes
3	Wheeler Mountain	869	Yes	No
4	Saddle Peak	807	Yes	No
4	Mount Ellis	1,290	Yes	No
4	Kelly Creek	813	No	No
5	5-Meter Mosaic (not USGS)	281	N/A	N/A
5	10-Meter Mosaic (not USGS)	69.2	N/A	N/A

NATIONAL WETLANDS INVENTORY (NWI) MAPPING

Information Provided by NWI

The National Wetland Inventory (NWI), administered by the U. S. Fish and Wildlife Service of the U. S. Department of the Interior, completed mapping of most of the project area in May of 2001. The NWI mapping was completed at the request of Lynda Saul (Wetlands Coordinator for the Montana Department of Environmental Quality) to assist with this project. The NWI mapping was based on stereoscopic analysis of CIR aerial photographs taken in July 1984. The aerial photographs used were at a scale of 1:58,000. Draft NWI maps were provided as blue-line copies of USGS 7.5-minute topographic maps, with the inventoried wetland features drawn on the blue-line maps. Table 4 above shows the USGS 7.5-minute map areas completed by NWI. Digital files of the wetland features mapped by the NWI were also provided. Information on the methods used for the NWI mapping was not provided with the maps and digital data.

Results

The NWI mapping was incorporated into the Gallatin County GIS system. This was completed by importing the digital files provided by NWI into the Gallatin County GIS system. This allowed for review of the areas mapped by NWI by overlaying the mapped areas on the 2001 CIR imagery developed for the project. It also allowed for side-by-side comparison of wetland areas mapped by NWI with wetland areas inventoried for this project, and allowed for summarizing the results of the NWI mapping, using the ArcView™ GIS software. The results are presented in Table 5.

Table 5
Summary of NWI Mapping of Wetlands

NWI Mapping (1984 Data)	Total Acres	% of Study Area	Maximum Size (acres)	Minimum Size (acres)	Feature Count
Wetlands	4,755	1.42%	209	0.01	2,449

The original plan was to review the NWI mapping and suggest any changes or corrections based on field inspections. It was decided that this was not practical because there was a 15-year gap between the CIR imagery used by NWI and the CIR imagery developed for this project. Without extensive field work there was no way to determine if wetland areas identified by NWI that were not visible on the 2001 CIR imagery were present in 1984. Instead the NWI GIS layer was used to help guide the construction of the current layer.

Differences that were noted include 1) NWI mapped ponds and open stream channels as wetland features while this project mapped them separately, 2) the river channels have migrated to the point that some areas mapped as wetlands by NWI are now gravel bars, 3) NWI mapped most of the irrigation ditches in the area as linear wetland features while this project did not, and 4) NWI mapped the main river channel areas as wetlands (especially the East Gallatin River), while this project mapped the meander corridor areas adjacent to the river channels as wetlands. Figure 7 shows a comparison of the NWI mapping and the mapping completed for this project with examples of differences.

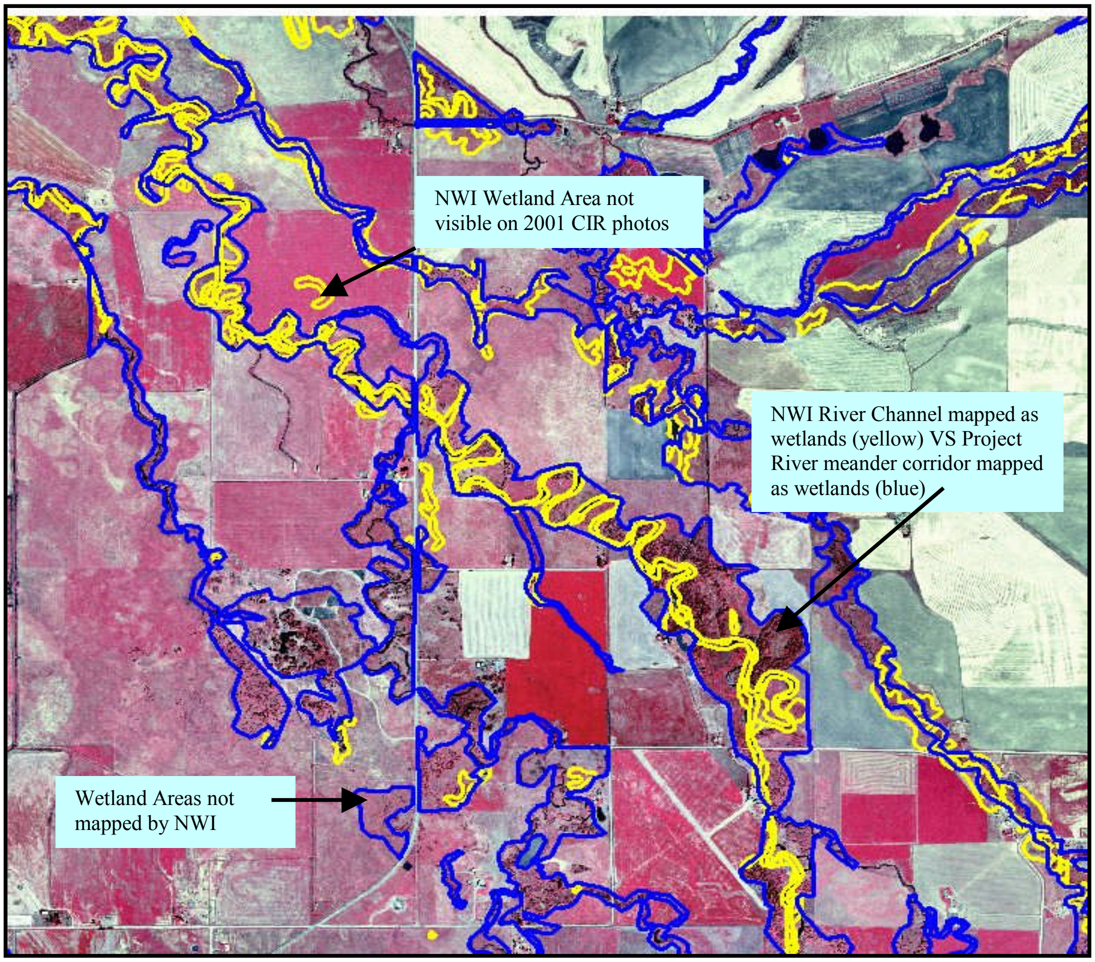

Figure 7. Comparison of areas mapped as wetlands by NWI (in yellow) with areas mapped as wetlands for this project (in blue).

ASSESSMENT OF CURRENT CONDITIONS

The CIR DOQs were used as base maps for constructing a Geographic Information System (GIS) database using ArcView™ version 3.3 software. This approach was used so that the data could be easily updated and compared to other spatial data sets. Additionally, existing reports containing information on wetlands were reviewed, several conservation easements were visited, many inventoried areas were ground-truthed, and low altitude aerial flights were conducted to inspect and photograph wetland and riparian areas.

Review of Subdivision Documents and Conservation Easements for Wetlands

The first step in the inventory of wetlands was to locate sites of known wetlands to see how the different types of wetlands appeared on the CIR imagery. Available reports containing information on the locations of wetlands, including in some cases delineated wetlands, were reviewed. The City of Bozeman Critical Lands Study, which included a map of wetland features around the Bozeman urban area, was included in the review. This report covered an area of about 8.5 miles along the north and west sides of the Bozeman urban area (Wetlands West, 1998).

Documents submitted to the Gallatin County Planning Department for subdivision approval were also reviewed. Many of these reports contained maps and other information on wetlands, including delineated wetlands. Table 6 lists the subdivision projects that were reviewed for wetland information.

Table 6
Subdivision Application Documents Reviewed for Wetlands

Project Name	Wetland Information In Report
Antelope Ridge	No
Baxter Meadows	No
Bridger Peaks Town Center	Yes
Cattail Creek	No
Day Ranch	Yes
Elk Grove	Yes
Falcon Hollow	Yes
Gallactic Park	Yes
Gallatin Park	Yes
Gallatin Center	No
Green Hills Ranch	Yes
Harry Piper Property	Yes
Harvest Creek	Yes
Lake Amended	No
Manley Meadows	Yes
Meadow Brook Estates	Yes
River Rock	No
River Rock Phase II	No
Saddle Peak	No
Stone Ridge	Yes
Sundance	No
Triple Tree	No
Valley Ice Garden	No
Valley West	No

Several properties in the project area with known wetlands and riparian areas were also visited with landowner permission. These properties either had conservation easements or were being considered for conservation easements. The sites visited included the FDD ranch near Manhattan, the Tim Crawford property northwest of Belgrade, and the Milesnick Ranch north of Belgrade.

Description of Wetland and Riparian GIS Layers
In order to inventory wetlands and riparian areas it was necessary to select the types of map units or "polygons" used to construct the GIS database. One problem encountered was that in many areas wetlands and riparian areas are mixed. For example riparian wetlands along the West Gallatin River were mixed with non-wetland riparian vegetation. To resolve this problem it was decided to create a GIS layer referred to as "***Wetlands***" if the area was clearly a wetland area and there was no significant canopy cover hiding the wetland plants from view on the CIR imagery. If the area contained trees and shrubs and the ground surface could not be viewed on the CIR imagery it was included within a GIS layer referred to as "***Riparian/Wetland Mixed***", to indicate the possible presence of wetlands under the riparian tree and shrub canopy cover.

Mapping Conventions
Minimum Mapping Unit - The minimum mapping unit size selected for the inventory was ½-acre for both the wetlands and riparian/wetland mixed layers. The minimum mapping unit is a measure of the smallest site consistently mapped throughout the project area. Several sites were identified that are smaller than the minimum mapping unit if they could be clearly identified on the CIR imagery, but it is likely that many smaller features were missed.

Split and Continuous Polygons - Many of the areas mapped were bisected by roads, residential developments, or features such as constructed ponds. In many instances these bisecting features still maintained wetland or riparian characteristics and were mapped as a continuous polygon (area). However, features such as major roads often created a large disturbance within the feature. As a convention, if the bisecting feature was wider than 8 meters for a wetland polygon, the mapped area was split to exclude the bisecting feature. If the bisecting feature was wider than 15 meters for a riparian/wetland feature it was split to exclude the bisecting feature. Examples of split and continuous polygons with bisecting roads are shown in Figure 8. The wider distance for the riparian class was introduced as a matter of parsimony, since the linear nature of these ecosystems often resulted in the occurrence of numerous bisecting features.

Split | Continuous

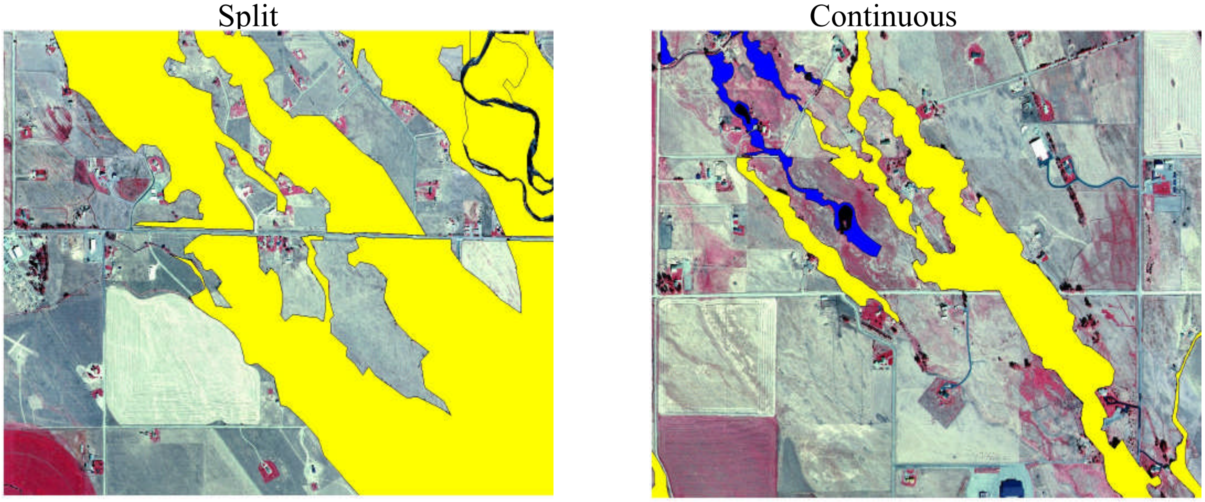

Figure 8. Examples of split and continuous riparian mapping polygons (yellow).

River Channel Mapping - The two primary river channels in this project are the East Gallatin and West Gallatin Rivers. The West Gallatin River floods with greater intensity than the East Gallatin. As a result, the river creates visible flood scarring that occurs both on the banks and on inter-channel islands. The flood-scarred areas are generally sand or gravel areas, with little or no vegetation, and appear light gray to grayish-green colored on the CIR imagery as shown in Figure 9. The lateral migration of the active channels is evident in the widespread flood scars that occur along the river corridor. To allow for future analysis of channel migration, the active river channels were mapped and added to the GIS database as a surface water layer.

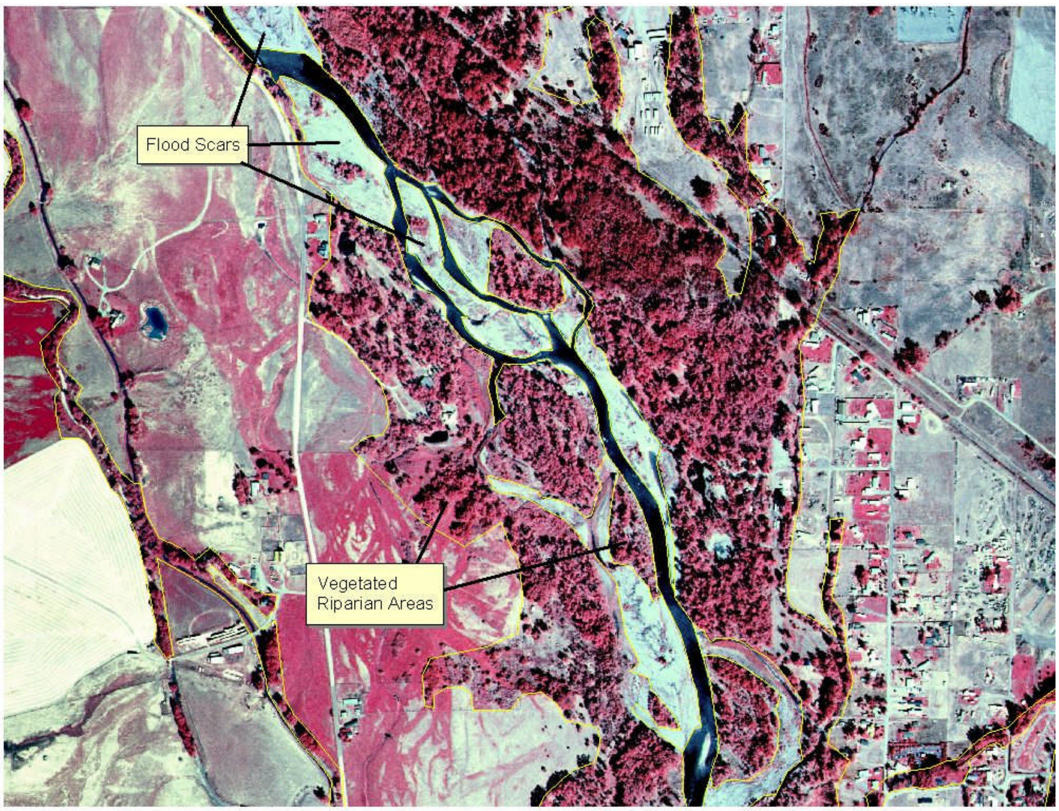

Figure 9. Example of flood scarred, vegetated, and active river channels along the West Gallatin River.

Analysis of Wetlands and Riparian Areas on CIR Imagery

After known areas of wetlands obtained from available reports and field inspection of conservation easements were mapped, the remaining wetland areas had to be inventoried by analyzing the CIR imagery. Early in the process, simultaneous analysis of the CIR imagery and additional field inspections were completed to aid in identification of wetland features on the CIR imagery. Identifying riparian areas was easier because the focus was on identification of woody riparian vegetation, which was readily visible on the imagery.

Differences in color, tone, and texture on the CIR imagery were used to aid in the inventory of wetland and riparian areas. In most cases, a bright red color on the photo generally indicates lush vegetation and low to moderate surface moisture, while a darker red color is displayed in vegetated areas with saturated or near saturated soils. Brighter colors such as yellow or white indicate that the vegetation and soil contain very little moisture and thus are generally not indicative of wetlands. Smooth textures, and uniform color usually indicate that the vegetation is of approximately the same height and forms a continuous canopy. One example of this would be a wet meadow where the grasses grow in close proximity to each other and the blades are of a similar blade height and shape. Areas of woody riparian vegetation, such as cottonwoods and willows, have several canopy levels and display a rough texture on the CIR imagery. Irrigated crops generally show up as uniform bright red areas with geometric shapes (circles and squares).

The dominant tree and shrub species were identified for each area inventoried. In areas with co-dominant tree and shrub species 2-3 species for each vegetation class were identified. Grassy vegetation was not documented due to the high diversity of grasses and the inability to distinguish different types of grasses on the CIR imagery.

Analysis of the colors and textures on the CIR imagery, along with ground-truthing of inventoried sites, allowed for identification of the larger trees and shrubs present in the area. This was harder for smaller shrub species, which were often estimated based on data from ground-truth sites. In addition to using color, tone, and texture on the CIR imagery to inventory wetlands, other sources of information were also used. A GIS layer was obtained from the Gallatin Conservation District for hydric soils. This layer showed hydric soils, as mapped by the Natural Resource Conservation Service (NRCS), divided into classes based on the percent of hydric soils within the soil mapping units. The layer could be viewed over the CIR imagery to see if hydric soils were present in a suspected wetland area. The GIS layer of the NWI data was also overlain to check areas for wetlands inventoried by NWI.

Ground-Truthing and Low Altitude Aerial Survey

Once the initial GIS layers were constructed for the inventoried areas using the CIR imagery, ground-truthing was completed to check the accuracy of the on-screen digitizing. The project area was divided into four quadrants and larger scale field maps were printed with the CIR imagery as a base and the inventoried areas shown on the maps. A one-day field training exercise was held to show project participants and volunteers how to check the sites inventoried. The field maps were then used along with a Wetlands Ground-Truth Survey Sheet to conduct the ground-truthing. A sample of a completed survey sheet is included in Attachment B. The survey sheet included questions on the vegetation, presence of surface water, saturated soils, landuse, and evidence of alteration.

Over 240 field sites were ground-truthed, including the sites visited while inspecting conservation easements. The locations of the sites visited were documented by either using a GPS unit, or by marking the position on the CIR field maps provided to the folks doing the ground-truthing. The sites marked on the field maps were entered into the GIS project using on-screen digitizing. A data layer was created for the GIS project to show all of the ground-truthing sites. This layer is shown in Figure 10 as it appears in the project.

Selected areas were also flown at low altitude in July of 2003 to inspect areas that were being mapped on the computer using the CIR imagery. Low altitude, oblique, natural color digital photographs were taken of selected sites for comparison with the CIR imagery and photographs taken while ground-truthing. Using the combination of computer mapping with the CIR imagery, ground-truthing, and low altitude aerial survey significantly improved the understanding of how and where land-use changes have impacted wetlands and riparian areas. Figure 11 shows how a riparian/wetland mixed site appears on the CIR imagery, from low altitude in natural color, and on the ground. Figure 12 shows how a wetland area appears on the CIR imagery and from low altitude in natural color.

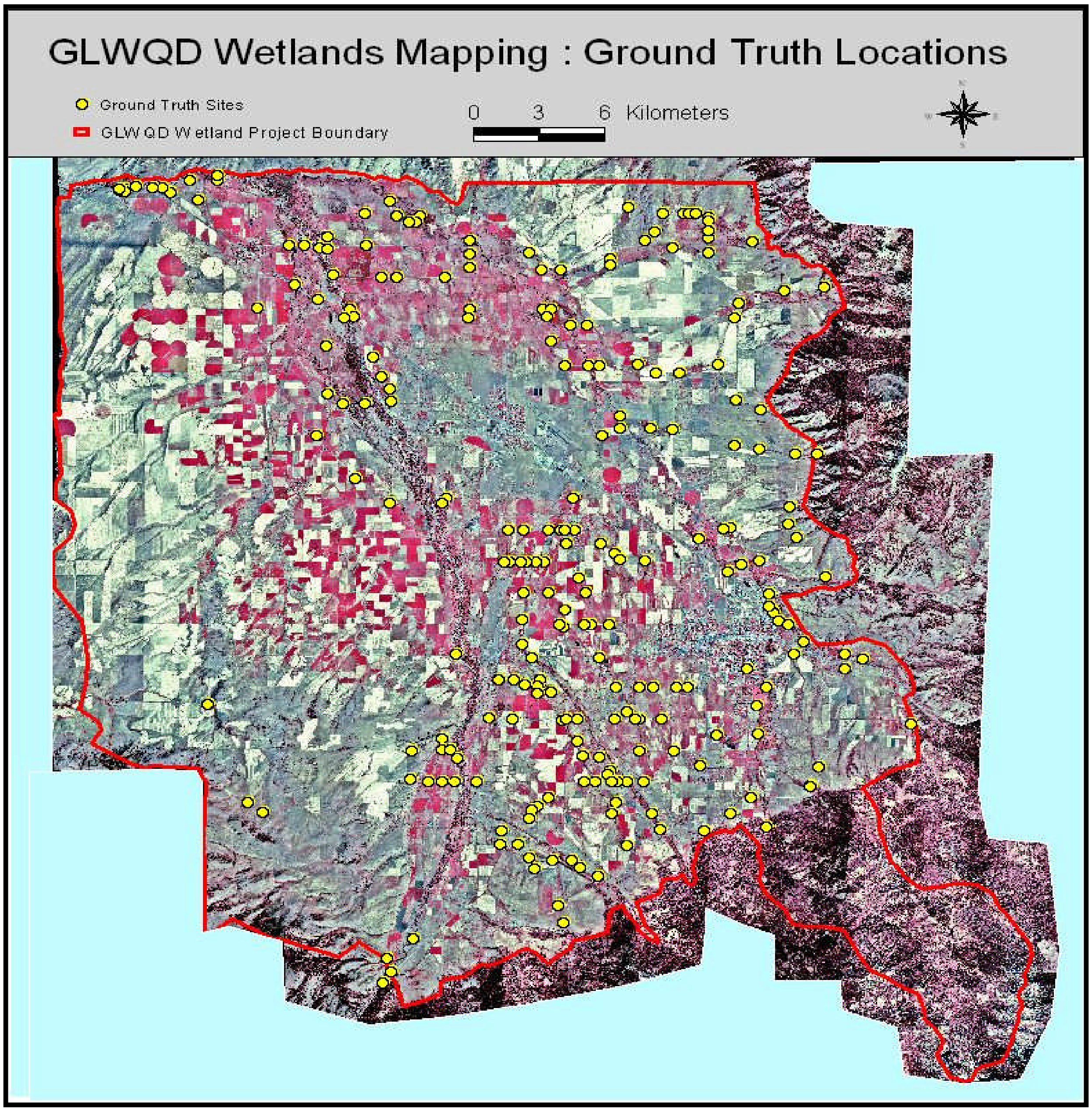

Figure 10. Locations of ground-truthed sites within the project area

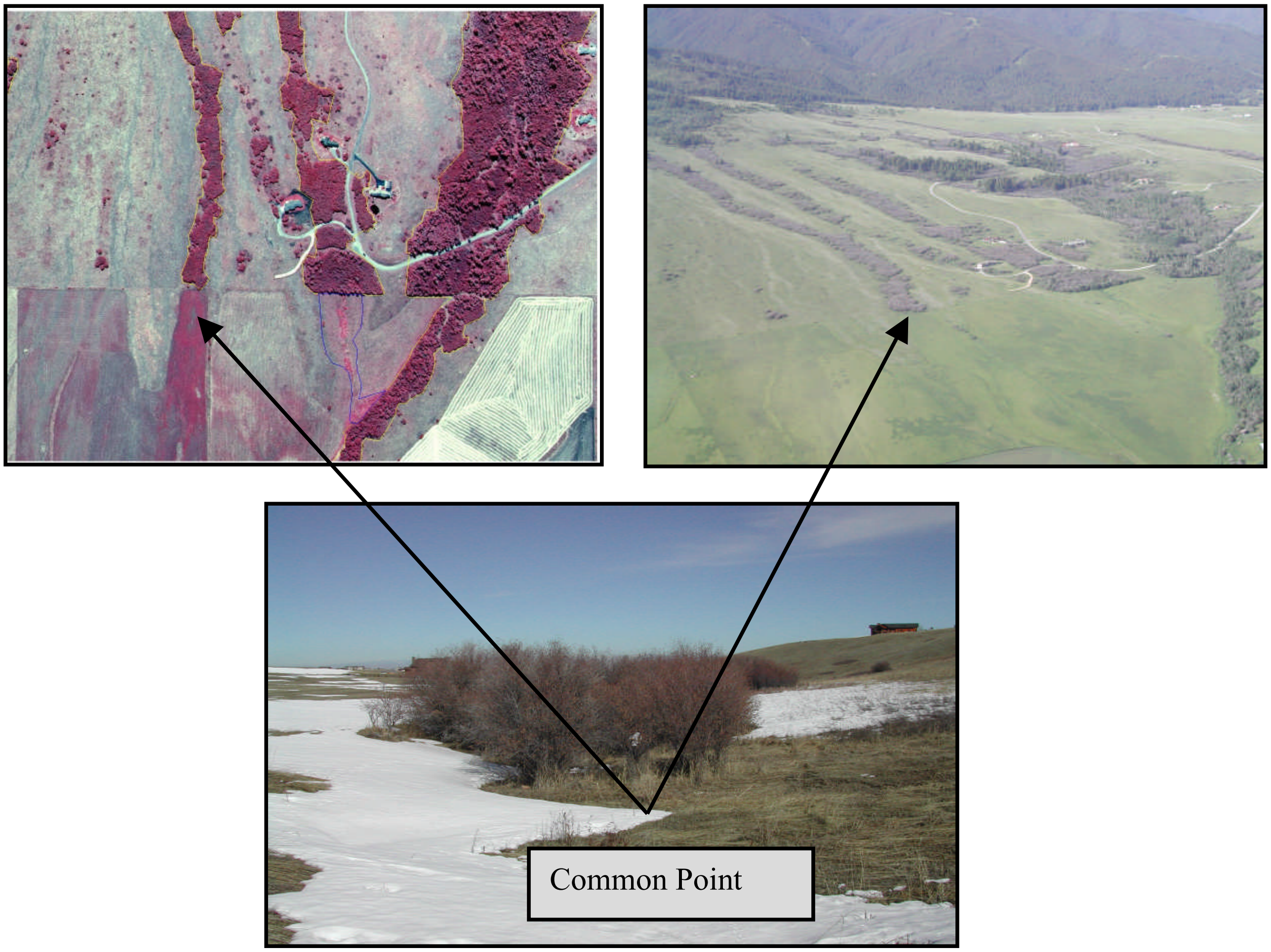

Figure 11. Example of a riparian/wetland mixed site as seen on CIR imagery, from low altitude in natural color, and from the ground.

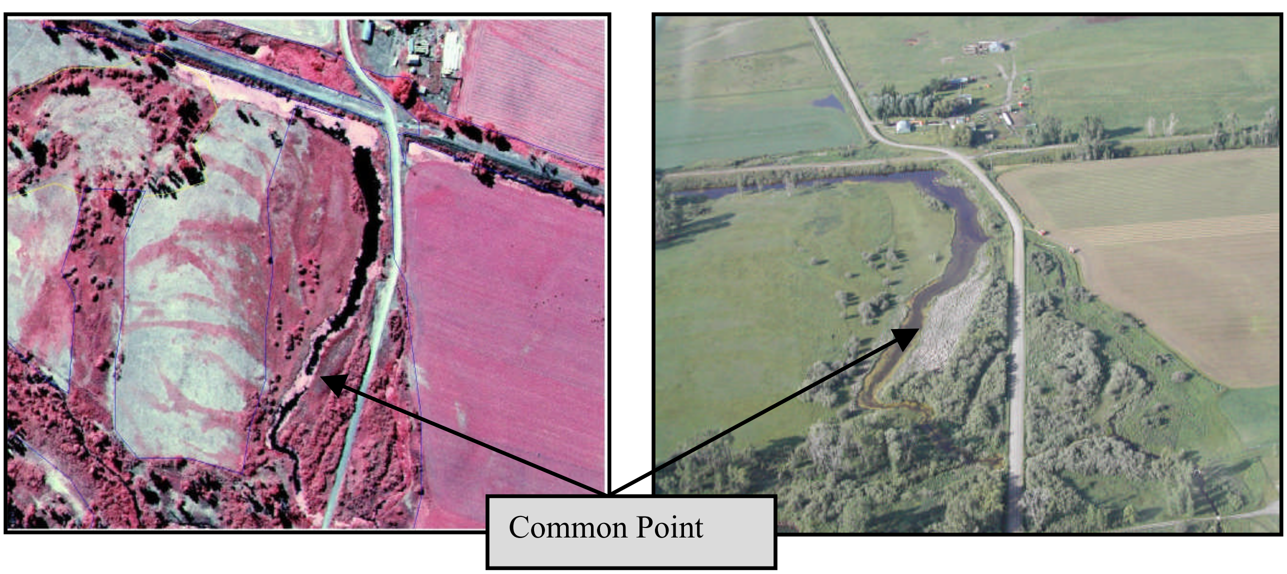

Figure 12. Example of a wetland site as seen on the CIR imagery and from low altitude.

Inventory of Wetlands and Riparian Areas
The areas inventoried as *wetlands* and *riparian/wetlands mixed* are considered representative of conditions as of 2001. Ground-truthing and the low altitude aerial flights were conducted through the summer of 2003. A map showing the inventoried *wetlands* and *riparian/wetlands mixed*, on the CIR base map, is provided in Attachment C. The map shows the "big picture" in terms of the spatial distribution of wetlands and riparian areas in the Gallatin Valley and upper Bozeman Creek watershed. Several regional patterns can be seen. The largest concentration of wetland features is in the north-northwestern portion of the valley. This area shows up on the CIR imagery as an area of continuous shades of red. Much of the land in this area is sub irrigated, with numerous springs and spring creeks. Ground water flow mapping by Hackett (1960), and Slagle (1995) shows that this area represents the regional ground-water discharge area for the Gallatin Valley aquifer system (see Figure 4, page 6).

The second largest concentration of wetland and riparian features is associated with the West and East Gallatin Rivers. Both these rivers support a continuous series of wetland and riparian areas. In the southeastern portion of the valley, numerous smaller, more linear wetland features are present, which follow the general pattern of the perennial drainages coming off of the Gallatin Range. These wetland features are more discontinuous. This area also includes several smaller wetland features formed on slopes that are supported by spring discharge or leaking irrigation ditches.

The northern and northeastern portion of the project area, including the Horseshoe Hills, lower Dry Creek Valley, and the southwestern facing flanks of the Bridger Range are relatively dry. Wetland and riparian features are limited in these areas to the perennial drainages. The western portion of the project area, which includes the Madison Plateau is also dry, but contains several isolated wetland and riparian areas associated with irrigation.

In the upper Bozeman Creek watershed numerous small wetland features were documented but many areas were smaller than the minimum mapping unit size of ½ acre. One exception is the Mystic Lake area, which contains several large wetland areas, and is visible on Attachment C. Mystic Lake was dammed in the past, but the dam has since been breached. A smaller lake now occupies the area. The land area that was previously flooded by the dam is now mainly wet meadow.

The impacts of human development can be seen on the map included as Attachment C. Even at the small scale of the map, a number of linear wetland areas can be seen that are in most cases the result of altered surface-water and ground-water flow patterns where roads and railroads have been built. Agricultural development shows up as a number of linear riparian/wetland mixed features associated with irrigation ditches. In the northwestern corner of the project area, south of Manhattan, return flow from irrigation on the Madison Plateau has created a number of artificial wetland and riparian features.

Table 7 summarizes the results of the inventory of wetlands and riparian areas, which represent an assessment of how much area these features presently cover within the project area. The total areas mapped in each category and the number and size range of mapped features are shown, along with the statistics for the NWI mapping for comparison.

Table 7
Summary of Inventoried Wetlands and Riparian/Wetlands Mixed Areas

2001-2003	Total Area	% Of Area	Largest Unit	Smallest Unit	Unit Count
Wetlands	8,981 Acres	2.7 %	706 Acres	0.31 Acres	405
Riparian/Wetlands	13,924 Acres	4.2 %	960 Acres	0.16 Acres	530
Combined Totals	22,905 Acres	6.9 %	N/A	N/A	931
NWI Results	4,755 Acres	1.4 %	209 Acres	0.01 Acres	2,449

The main wetland types present with the *wetlands* layer are summarized in Table 8. Marsh areas often contained a variety of willows along with cattails and emergent vegetation. Wet meadows proved to be the most diverse wetland type in the Gallatin Valley. The wet meadow classification includes those areas immediately adjacent to river and ponds, sites down-slope of leaking irrigation or drainage ditches, low-lying areas of irrigated pastures, and areas immediately up-slope of road beds. Wet meadow areas were most commonly composed of grasses, sedges and some forbs, with minimal populations of shrubs or trees. Wet meadow wetlands covered a total area of 3,170 acres and represent 35% of the total area inventoried within the *wetlands* layer.

The dominant types of wetlands inventoried within the *wetlands* layer were riparian and wet meadow wetlands. Many of the wetland areas contained mixed wetland types. Note that the areas shown in Table 8 do not include the wetlands within the *riparian/wetlands mixed* layer. Over 50% of the areas mapped as *wetlands* were classified as riparian wetlands, covering an area of 4,740 acres. This statistic suggests that additional land area within the project contains riparian wetlands that could not be seen on the CIR imagery and are included in the *riparian/wetlands mixed* layer. If the wetlands included within the *riparian/wetlands mixed* layer were included the total area of wetlands in the Gallatin Valley would be significantly greater than the 8,981 acres inventoried in the *wetlands* layer.

Table 8
Summary of Dominant Wetland Types in the *Wetlands* GIS Layer

Wetland Type	Unit Count	Total Area (Acres)	% Total Wetland Area (8981 Acres)
Marsh	20	204	2.3
Riparian	186	5,611	62.4
Wet Meadow	199	3,174	35.3
Total Wetlands	**405**	**8,989**	**100**

GIS Project CD

To make the information compiled for the project available to the public a GIS data CD was created. The final GIS database constructed for the project contains the layers constructed for "*wetlands"* and "*riparian/wetlands mixed"*. The project also contains a significant amount of related data. The GIS data CD is available from the Gallatin Local Water Quality District, with the following information:

1) A 5-meter resolution CIR image of the entire project area
2) The *Wetlands* GIS layer (shapefile)
3) The *Riparian/Wetlands Mixed* shapefile
4) A shapefile showing the maximum historical extent of wetlands and riparian areas
5) A shapefile for the NWI wetlands inventory
6) A shapefile for the project area boundary
7) A shapefile for the ground-truth sites
8) A shapefile showing areas of hydric soils
9) A JPEG file of a map showing the historical and current conditions

Attributes of the *Wetlands* GIS Layer

As previously mentioned, the intent of this project was to identify areas exhibiting the hydrologic and vegetative characteristics of wetlands. ***The areas inventoried as wetlands do not represent delineated jurisdictional wetlands***. Conservatively speaking, all of the areas inventoried are considered ecological wetlands, although the soil and hydrologic conditions may not always satisfy legal requirements of a wetland. The following descriptions are provided for the attributes contained in the data table associated with the wetlands layer in the GIS project:

Area (m^2) = Total areal coverage of a particular wetland polygon.

Perimeter (m) = Total linear distance of the lines defining the wetland.

Acres = Total areal coverage of a particular wetland polygon in acres.

Hydrology = A statement of the basic hydrologic conditions in a mapped polygon.
Surface (*Surf*) means that standing or running water is visible on the site. *Soil* indicates that the moisture on the site is primarily contained as soil moisture.

Draining = This attribute may be used in reclamation efforts by identifying wetlands that have previously been or are currently being drained.
Y = Yes, draining is visible on this site.
P = Possible draining on this site, or on adjacent parcels.
N = No, visible signs of draining associated with this site.

Tree Species = A listing of the dominant tree species present, listed in order of decreasing dominance. Dominance was determined by the species occupying the largest percentage of the mapped area.

Shrub Species = A listing of the dominant shrub species present, listed in order of decreasing dominance. Dominance was determined by the species occupying the largest percentage of the mapped area.

Wetland Type = These descriptions are categorizations of visible wetland characteristics. Many wetland polygons are complexes involving one or more of the following wetland types.
Wet Meadow = Areas dominated by grass and/or forbs that occur in low-lying areas of grasslands or agricultural fields.
Riparian = Areas dominated by tree and shrub vegetation that occur on the periphery of rivers, streams, and irrigation or drainage ditches. Surface water or extremely high soil moisture can be seen through the vegetation canopy at these sites.
Marsh = These areas are dominated by standing water and often contain emergent hydrophilic vegetation.

Influences = This attribute field is used to list any extraneous factors associated with this particular wetland feature.
Constructed (artificial) ponds = Wet meadows and marshes often form immediately upstream or downstream of excavated pond sites.
Roadbed = The presence of railroad, highway, or unpaved roads changes hydrologic flow patterns. As a result marsh, riparian, and wet meadow wetlands form as surface and subsurface flow is blocked by roadbed features.
Irrigation drainage = Local topographic variation occasionally leads to the concentration of runoff from agricultural irrigation systems. This concentrated runoff collects in small depressions, resulting in the formation of wet meadows or marshes.
Irrigation canal = Sharp bends, debris or other constrictions of irrigation canals may lead to water leakage over the top or through the sides of the canal walls. Combinations of fine grained soils and depressional topography in the areas down-gradient of the leak can lead to the formation of wet meadow or riparian wetlands.
Residential (Res) Development = The presence of residential buildings and landscaping often creates distinct breaks in natural hydrologic conditions. The effects of human activities near wetland areas could alter the size or ecological health of associated wetlands.

Attributes *of Riparian/Wetland Mixed* GIS Layer
The GIS layer showing the current condition for the *riparian/wetlands mixed* layer is shown on the map included as Attachment A. The *riparian/wetland mixed* GIS layer includes areas immediately adjacent to streams and rivers that are typically dominated by cottonwood, willow, alder, and occasionally aspen trees. Willows may be classified as either trees or shrubs. In the attribute table for this layer they were placed in the tree-vegetation class. Additionally, the riparian/wetland mixed layer also includes some of the drier sites that support juniper trees along with hawthorne, chokecherry, and snowberry shrubs. The following descriptions are provided for the attributes contained in the data table associated with the riparian/wetlands mixed layer in the GIS project:

Area (m^2) = Total areal coverage of a particular wetland polygon.

Perimeter (m) = Total linear distance of the lines defining the wetland.

Acres = Total areal coverage of a particular wetland polygon in acres.

Tree Species = Lists the dominant trees present in order of decreasing dominance.

% Woody Vegetation = Estimated percentage of the area covered by woody vegetation.

Shrub Species = A listing of the dominant shrub species present, listed in order of decreasing dominance. Dominance was determined by the species occupying the largest percentage of the mapped area.

Notes = Observations of human or natural conditions with the feature.

Constructed (artificial) ponds = Wet meadows and marshes often form immediately upstream or downstream of excavated pond sites.

Roadbed = The presence of railroad, highway, or unpaved roads changes hydrologic flow patterns. As a result marsh, riparian, and wet meadow wetlands form as surface and subsurface flow is blocked by roadbed features.

Irrigation drainage = Local topographic variation occasionally leads to the concentration of runoff from agricultural irrigation systems. This concentrated runoff collects in small depressions, resulting in the formation of wet meadow or marsh wetlands.

Irrigation canal = Sharp bends, debris or other constrictions of irrigation canals may lead to water leakage over the top or through the sides of the canal walls. Combinations of fine grained soils and depressional topography in the areas down-gradient of the leak can lead to the formation of wet meadow or riparian type wetlands.

Residential (Res) Development = The presence of residential buildings and landscaping often creates distinct breaks in natural hydrologic conditions. The effects of human activities near wetland areas could alter the size or ecological health of associated wetlands.

W. Gallatin/E. Gallatin:

Flood scar = Sites along the banks of a river where recent floods have removed the majority of established vegetation.

Corridor = Vegetated sites that are immediately adjacent to the river system named.

Island = An isolated site that was formed by the braiding and subsequent rejoining of a primary river channel.

Gallatin Corridor = is a geographic location entry used to indicate the riparian sites located downstream of the confluence between the East Gallatin and West Gallatin rivers.

HISTORICAL IMPACTS FROM HUMAN ACTIVITIES (1800-2001)

Two subcontractors were hired to complete historical research to obtain information on how and where wetlands and riparian areas have been altered or lost due to human activities in the Gallatin Valley. This historical research focused on changes since human settlement in the area started around 1840. Valerie Harms conducted oral history interviews and literature research to collect information on the historical presence of wetlands, and the human activities that have impacted them. Curtis Kruer analyzed old aerial photography and used other existing spatial data to map the maximum historical extent of wetland and riparian areas in the Gallatin Valley. Combined, these two efforts shed light on how and where human activities in the Gallatin Valley have impacted wetland and riparian areas.

Oral History Interviews as Insight

Interviews conducted by Valerie Harms provided insight into some of the common human activities that have resulted in changes to wetland and riparian areas. Oral interviews were provided by Dean Adams, Dan Langohr, Marcia Youngman, Dave Wessell, and Kate Moore. The following summaries are provided from those interviews.

Mr. Dean Adams-Dean Adams lives in Bridger Canyon on the East side of the Bridger Mountains. This area is outside the project area, but the information provided gives good examples of human impacts to wetlands. It was reported that in the late 1800's the previous owner of the property plowed up beaver ponds and wetlands on the property to make pasture. He also noted that several property owners in the area have attempted to straighten Bridger Creek to make it easier to hay.

Mr. Dan Langhor- Dan Langor's family operated the Langhor Greenhouse along Bozeman Creek for many years. A spring creek ran behind the property. His family constructed a pond using the creek in the 1930s to provide irrigation water for plants grown outside the greenhouse. The construction of the pond altered flow patterns and resulted in the formation of some small wetland features. He noted that in the 1970s this land was purchased and apartments were built. The pond was closed due to some accidents that occurred.

Ms. Marcia Youngman-Marcia Youngman has lived in the Bozeman area for many years and is a former Mayor of the City of Bozeman and an active City Council member. She provided perspective on the challenges the City of Bozeman has faced dealing with wetlands and floodplain issues. She stated that much of the land area now occupied by the City of

Bozeman was reported to be either wetland or riparian habitat. Some of this habitat resulted from the presence of numerous beaver ponds. It was also noted that a road built north of Durston near Harvest Creek subdivision created an unintended artificial wetland, and that Bozeman Creek had been straightened in the Sundance Springs development.

Mr. Dave Wessell- Mr. Wessel also lives along Bozeman Creek (Sourdough Creek), south of Bozeman. He remembered the "swamp/lake" at Langhor's and played there when he was a child. He noted impacts to wetland and riparian features north of the City of Bozeman when Interstate (I-90) was built. He also stated that wide spread suburban development is having a negative impact on wetlands.

Ms. Kate Moore- Ms. Moore is a Bozeman native that lives on 100 acres near Nash Creek and Bozeman Creek, south of Bozeman. She noted that many of the springs in the area have dried up. Several man-made ponds have been built in the area, which may be impacting the streams and springs.

The Pattern of Human Activity

In addition to the oral history interviews, Valerie Harms researched library documents, old newspaper articles, museum documents, and discussed wetlands and riparian areas with local resource managers. Combined with the oral interviews, a general pattern of human activities in the Gallatin Valley that have impacted wetland and riparian areas emerged. In general chronological order from earliest activities to current activities the following activities appear to be the most significant:

1. Trapping of beaver and significant reductions in beaver populations.
2. Agricultural development
3. Construction of transportation corridors (roads and railroads)
4. Urban development
5. Suburban development and associated decline in agricultural land uses

Declining Beaver Populations

The historical influence of beaver on the spatial distribution of wetlands and riparian areas is incalculable, but probably significant. Large numbers of beaver would have resulted in the creation of numerous ponds, alteration of stream cannels, and significantly greater backwater areas than are present today. Documentation of extensive beaver populations in the Gallatin Valley extends back to the time of the Lewis and Clark expedition. On the return trip in 1806 Captain Clark recorded the following journal entry while crossing the Gallatin River: *" Struck the river (Gallitines) and crossed several chanels of the river running through the bottom in defferent directions. I proceeded on about two miles crossing those defferent chanels all of which was damed with beaver in such a manner as to render the passage impractical*." Mr. Greg Munther, former USFS District Ranger for the Gallatin National Forest, stated that before 1800 beaver influenced most streams and rivers in the area. As previously mentioned, Dean Adams stated that the former owner of his land on Bridger Creek plowed up a beaver pond. Overall the impact of significantly reducing beaver populations in the project area by trapping is considered to be the first human activity that resulted in decreases in wetland and riparian habitat in the Gallatin Valley.

Agricultural Development
Most of the early settlement in the Gallatin Valley was associated with agriculture. Farming and ranching have both been important economic activities and remain so today. As seen on the CIR imagery shown on Attachment C, a significant percentage of the land usage in the Gallatin Valley is still agricultural. On Attachment A crop lands show up as bright-red geometric shapes if they were still being irrigated when the photographs were taken, or as white to dark brown geometric shapes if they were already harvested or in fallow. Pasture lands are harder to spot on the CIR imagery, but often show up as areas with grey tones if the pastures are not irrigated, or as mottled shades of pink and red if sub irrigated or irrigated.

The earliest documented agricultural activity dates back to the 1860s. Crops were being grown in the Reese Creek area in 1846 (Bates, 1994). Historical aerial photographs show that by 1937 much of the land in the Gallatin Valley was being used for ranching or farming. By 1953 over 111,000 acres were being irrigated within the Gallatin River basin, with most of this irrigation occurring within the Gallatin Valley (Montana State Engineer's Office, 1953). The earliest documented irrigation ditches were the Penwell and Babcock ditches constructed in 1964 to divert water from the East Gallatin River. The Flannery ditch was constructed in 1868 to divert water from the East Gallatin River. Construction of ditches to divert water from the West Gallatin River began at about the same time with construction of the Heeb ditch (1865), Mammoth ditch (1866), Lewis Ditch (1870), and numerous others. Most of the other ditches were constructed between 1880 and 1900. These ditches include several large projects such as the Warm Springs Canal (1889), High Line Canal (1890) and the Low Line Canal (1899-1901). These canals had a collective length of over 90 miles (Montana State Engineer's Office, 1953).

Agricultural activities have had both positive and negative impacts on wetland and riparian features in the Gallatin Valley. Overall the impact has been to reduce the areas covered by both wetland and riparian areas. In many places wetlands have been drained to improve the land for farming. Many sub-irrigated areas that were probably historical functioning wet meadows are grazed during the dryer times of the year. A common impact has been the clearing of riparian vegetation to allow for better grazing, and hay production. Construction of the existing network of irrigation ditches and canals resulted in the creation of significant linear riparian and wetland features. These features were well documented by the NWI discussed earlier. Some isolated sloping wetlands have been created where irrigation water leaks or seeps from ditches on higher ground, or discharges in low areas below irrigated fields. Figure 13 shows an example of riparian features developed in drainages as a result of runoff from irrigated fields. Figure 14 shows examples of areas where wetlands have been drained, and where riparian vegetation has been cleared for agricultural purposes.

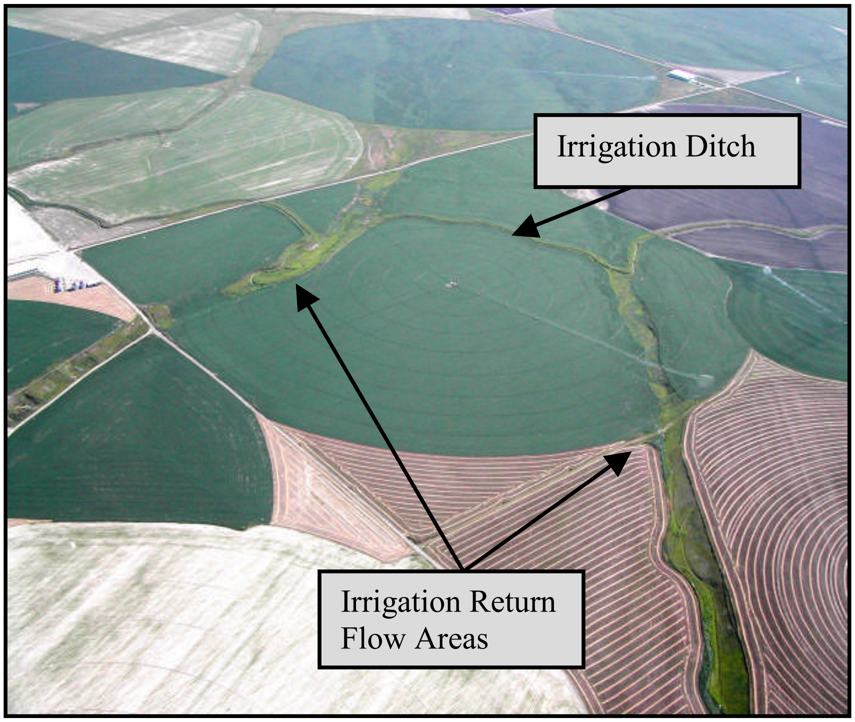

Figure 13. Riparian features created by runoff from irrigated fields

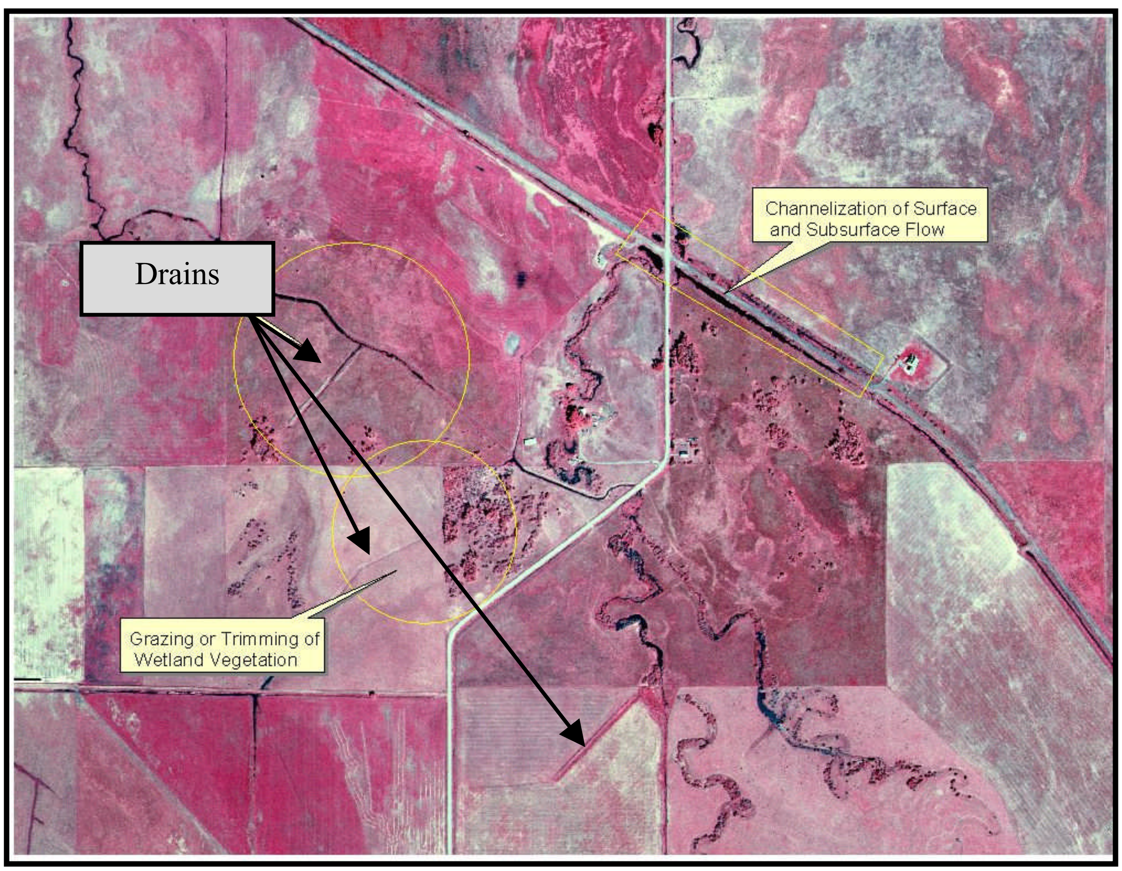

Figure 14. Examples of impacts to wetlands and riparian areas from human activity.

Construction of transportation corridors
Construction of roads and railroads has also had a significant impact on both wetland and riparian areas. The Interstate-90 corridor, which includes a railroad, frontage road, and utility lines, cuts across the Gallatin Valley from southeast to northwest (see Attachment C). This transportation corridor cuts across the regional surface water and ground water flow patterns, which are generally from south to north. In many cases road/railroad beds altered surface water flow patterns by damming surface water on the uphill side and reducing surface and subsurface flow on the downhill side. An example of this impact is shown on Figure 14, where an old railroad bed has altered flow patterns. Figure 15 shows another example of a wetland area created by alteration of surface and shallow subsurface flow. The area downslope of the roadbed is now being used for agriculture, but was probably much wetter prior to construction of the roadbed. The site is shown as seen on the CIR imagery and from low altitude in natural color.

Figure 15. Example of wetland created/altered by construction of roadbed, as seen on the CIR imagery and from low altitude in natural color

Urban development
The first documented settlement was established in 1862 and was known as Gallatin City (State Engineer's Office, 1953). Gallatin City was located at the mouth of the Gallatin River and was also referred to as East Gallatin. Bozeman was established in about 1864, followed by Belgrade in 1883, and Manhattan in 1884. Urban development has generally resulted in a decrease in wetland and riparian habitat due to the intensive land use changes within the urban areas. Urban development associated with the growth of Bozeman appears to have had the largest impact. Much of the land area now occupied by the City of Bozeman may have been covered by wetlands and riparian areas. The NRCS soils data maps most of the area as urban, so no information was found to verify the presence of hydric soils in the area. Bozeman Creek has been significantly altered by this urban development, and flows underground through the present downtown area.

Construction along the northwest, north, and south margins of the present urban area often require pumping of shallow ground water to dewater the area prior to building foundations. Recent commercial development along the north 19th Street area (northwestern margin of the City of Bozeman) has resulted in the alteration of both wetland and riparian habitat. Figure 16 shows a small, altered wetland associated with urban commercial development.

Figure 16. Modified wetland associated with commercial development in Bozeman

Urban development associated with the growth of Belgrade, which is currently one of the fastest growing cities in Montana, does not appear to have had much of an impact on riparian and wetland features. The Belgrade area is generally underlain by coarse gravels, is located away from major rivers and streams, and has depths to ground water in excess of 20 feet. This area appears to have always been relatively dry and well drained.

Suburban Development

Suburban development has increased significantly over the last 20 years in the Gallatin Valley. As previously stated (page 1), since the 1980's about 80% of the wetland loses nationwide are due to non-agricultural development, much of that is associated with suburban development (Brown & Lant, 1999). Suburban growth has had widespread impacts on wetlands and riparian areas. In previously undeveloped areas suburban development has displaced or altered wetland and riparian habitat. Suburban development in areas that were previously being irrigated, may also be resulting in declining ground water levels locally due to loss of artificial ground-water recharge from the irrigation. The declining ground water levels can result in drying of wetland and riparian features in low lying areas that have relied on the excess irrigation water. Analysis of the potential impacts from land use changes from irrigated agriculture to suburban development were beyond the scope of this project. Figure 17 shows an example of the displacement of wetland and riparian habitat by suburban development north of Bozeman as seen on the CIR imagery and from low altitude in natural color. Much of this area is underlain by hydric soils, which suggest that wetland and riparian features were historically more extensive.

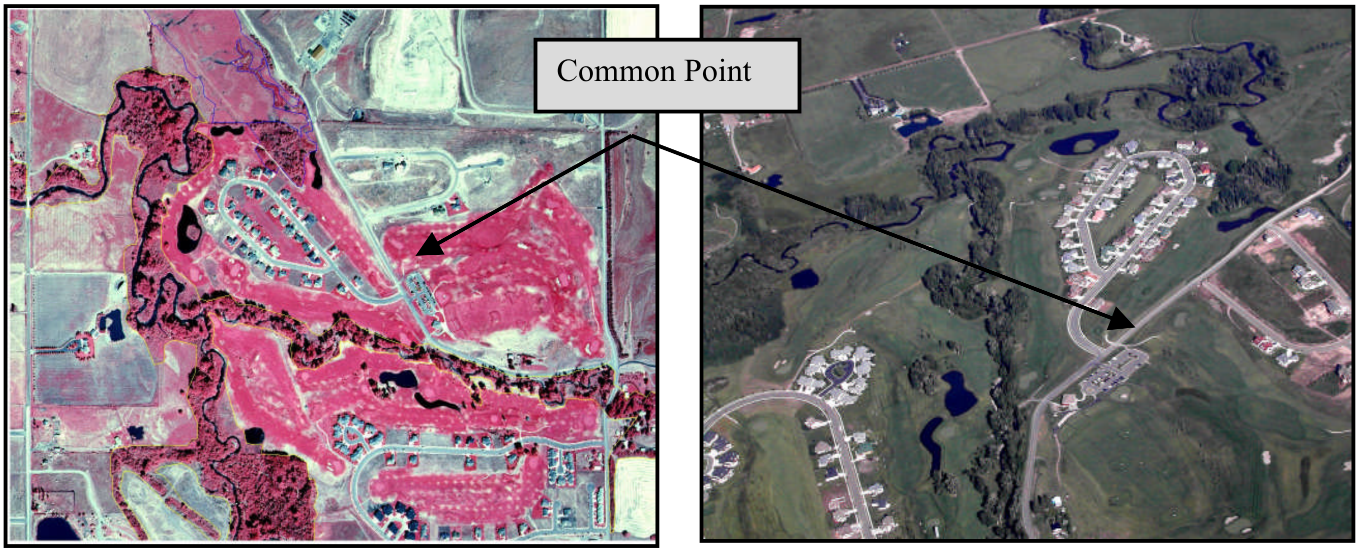

Figure 17. Example of impacts to wetland and riparian areas from suburban development

MAXIMUM HISTORICAL EXTENT OF AQUATIC HABITATS

Curtis Kruer constructed a GIS layer showing the "maximum historical extent of aquatic habitats" within the project area using ArcView™ GIS software. The term aquatic is used rather than wetland and riparian because the final GIS layer created also includes areas covered by ponds, streams and rivers. For purposes of creating this layer, circa 1800 was chosen as the reference time. Prior to 1800, humans were present in the valley but there was no significant human settlement. A number of sources including local, state, and federal agencies; state, university, and private libraries and museums; and communication with knowledgeable local residents, were used. The final GIS layer created is shown on a map included as Attachment D.

Historical Mapping Methods

The results of the historical research were used in conjunction with photo interpretation of historical aerial photography, topographic maps, floodplain maps, hydric soils data, ground water level data, current (2001) maps of wetland and riparian habitats, field surveys, and best professional judgment to locate the boundaries of the maximum potential extent of aquatic habitats in the Gallatin Valley. The following resources were used:

1) National Hydrography Dataset from USGS (digital)
2) 1937 aerial photographs of the Gallatin Valley (fairly complete set)
3) 1959 aerial photographs of the railroad corridor between Bozeman and Manhattan
4) 1995 black and white DOQQs of the project area (large prints and digital files)
5) 1995 black and white DOQQ mosaic of project area (large print and digital file)
6) NRCS hydric soils digital data (extrapolated from digital soils maps)
7) FEMA floodplain maps (prints and digital files)
8) 2001 CIR imagery
9) 2001 inventoried wetlands layer
10) 2001 inventoried riparian/wetland mixed layer

On screen digitizing of the boundaries for the maximum historical extent layer was performed using the 2001 CIR imagery developed for the project as a base layer. Digitizing was typically accomplished at an on-screen scale of approximately 1:8,000 with a minimum mapping unit for the historical extent of roughly 5 acres. Reconstruction of the historic boundaries was performed using 1937 aerial photographs as the primary data source. Unfortunately considerable alteration of aquatic habitats had occurred by that time.

Selected historical photographs were scanned to create digital historic images. These historic images, along with other digital data (e.g. topography, hydric soils, ground water, floodplain) could be displayed side-by-side in ArcView™ to aid in mapping and photo interpretation. The 2001 wetlands and riparian/wetlands mixed layers created by the Gallatin Local Water Quality District were merged in GIS to create a master shapefile. This master shapefile was then expanded utilizing the other data sources. Obvious artificial wetland and riparian habitats (i.e. along irrigation ditches, downslope from large irrigation ditches, etc.) were deleted from the historical extent coverage, leaving only naturally occurring aquatic habitats.

The digital National Hydrography Dataset (NHD) was acquired from the Montana Natural Resource Conservation Service (NRCS). This dataset shows the spatial distribution of rivers, streams, ponds, and lakes. The NHD data was imported into ArcView™ GIS and converted to a shapefile. The NHD shapefile was then edited to remove any obvious manmade features, leaving only natural occurring water bodies. Wetland and riparian corridors may have existed along many of the intermittent streams in the foothills and mountains around the valley edge but were often too narrow to be mapped for this project with the available resources. These streams, therefore, appear as digitized lines in the GIS coverage. Many streams (or reaches of streams), especially in the valley floor, had been destroyed or relocated prior to the creation of the NHD and even using old imagery, their historic alignment could not be located for mapping.

A GIS dataset was also obtained from NRCS that contained areas of hydric soils with a classification based on the percent of hydric soils within the data layer. It was also edited to remove any features that appeared to be man-made, leaving only naturally occurring features. The hydric soils layer was then edited to show only areas where the hydric soils mapping units contained 50% or more hydric soils. The final edited NHD and hydric soils shapefiles were then merged with the master shapefile to create the final master shapefile. Once this master shapefile was constructed the other data, including old aerial photographs, FEMA floodplain maps, and the CIR base map imagery were used to review and edit the layer.

Analysis of the Maximum Historical Extent GIS Layer
The final layer showing the *maximum historical extent of aquatic habitats* is shown on Attachment D in light blue. The 2001 *wetlands* layer and 2001 *riparian/wetland mixed* layer are shown on top of the maximum historical extent layer to allow for comparison of historical and current conditions. Figure 18 shows an example of the *maximum historical extent of aquatic habitats* layer on the CIR base map, in the area of Gallatin Gateway. Gallatin Gateway is located in the south central portion of the project area, near the Gallatin River. Figure 19 shows this same area in CIR without the data layers, and as seen on 1937 aerial photographs.

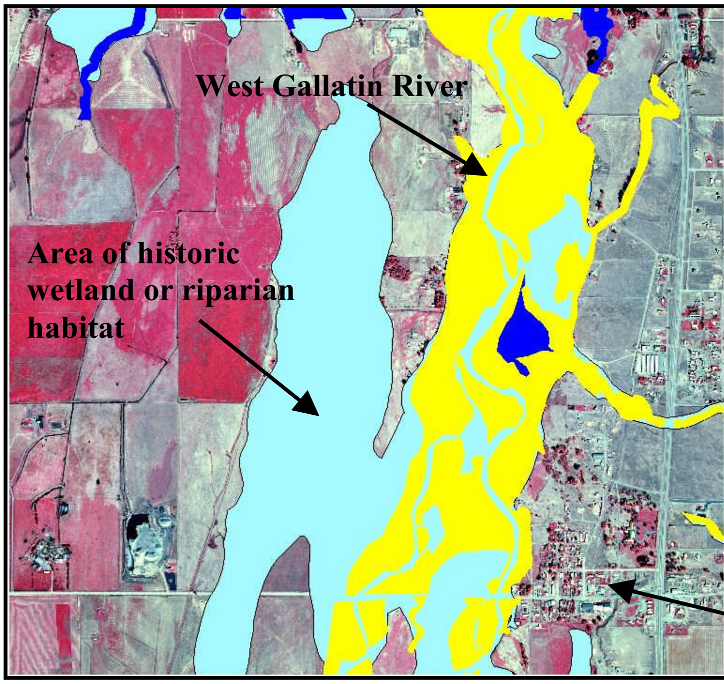

Figure 18. Example of GIS layer showing the *maximum historical extent of aquatic habitat* (light blue) with the 2001 *wetland* layer (dark blue) and 2001 *riparian/wetland mixed* layer (yellow) for comparison.

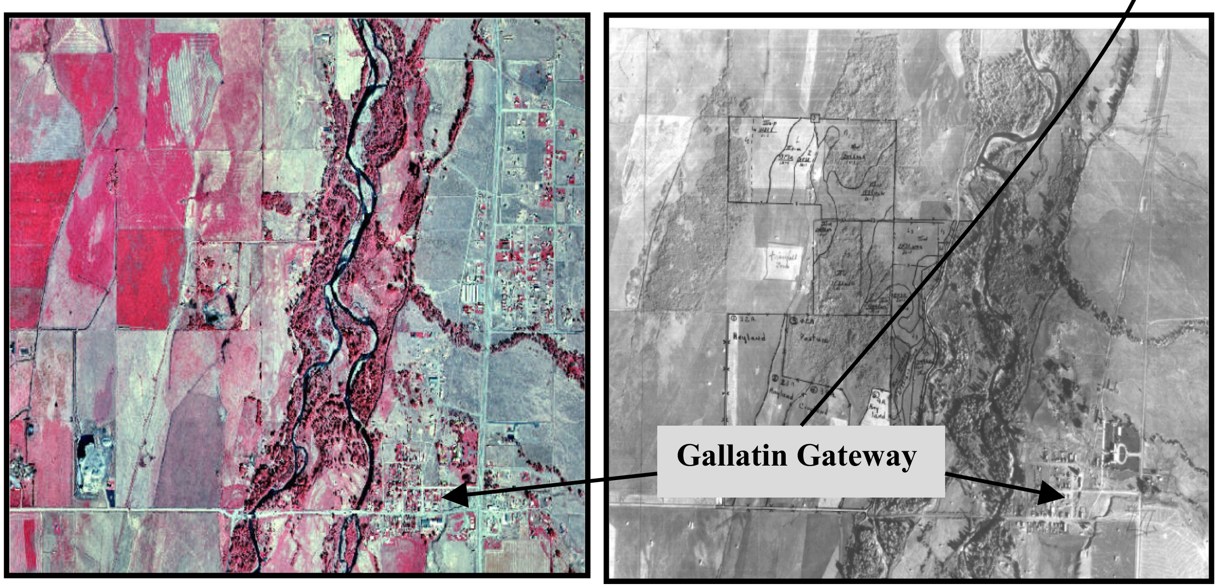

Figure 19. Comparison of Gallatin Gateway area as seen on CIR base map from 2001 and black and white aerial photograph from 1937.

The GIS software was used to calculate the difference in area between the maximum historical extent and the wetland and riparian areas mapped on the 2001 CIR imagery. The results are shown in Table 9.

Table 9
Area Comparison of Historical and Current Habitats

GIS Layer	Area (acres)	% of Project Area
Max. Historical Extent (circa 1800)	59,849	17.9
2001Total Wetland and Riparian Combined	22,904	6.9

The GIS comparison shows that prior to 1800 close to 60,000 acres of aquatic habitat may have been present in the Gallatin Valley. Based on the mapping of current conditions about 22,900 acres are currently covered by either wetland habitat or mixed riparian/wetland mixed habitat. If the maximum historical extent of aquatic habitats is compared directly to the areas mapped for 2001, the data suggests that only about 38% of the original habitat remains. This compares with a national average of 46% of historical wetland areas remaining. While there are errors and limitations associated with the GIS layers used for the comparison it provides a good overall assessment of the changes that have occurred.

Analysis of Focus Areas using Historical Aerial Photographs
To gain a better understanding of the changes that have occurred in wetland and riparian habitat in the Gallatin Valley, three focus areas were selected where good historic aerial photograph coverage was available. The focus areas were reviewed for examples of the changes over time due to drainage, irrigation, livestock, road and railroad construction, dredging and filling for development, removal of beavers, channel shifts, and the like.

Curtis Kruer created scanned images of selected black and white aerial photographs using the 1937 NRCS photographs and the 1959 railroad photographs obtained from the Museum of the Rockies. These scanned images were compared to the 2001 CIR imagery. Photo legends were overlain on the CIR imagery to show the areas covered by selected historic photographs. The black and white scanned images were not orthorectified, so spatial analysis of the changes could not be completed using ArcView™ GIS software.

The three focus areas selected were 1) the Gallatin Gateway area, 2) an area along the East Gallatin River, and 3) an area near Manhattan where Interstate 90 crosses the West Gallatin River. In the Gallatin Gateway area a significant decrease in riparian vegetation cover can be seen by comparing the 2001 CIR imagery with the 1937 black and white photograph (Figure 19). The most obvious changes appear west of the West Gallatin River and northwest of Gallatin Gateway. The visible changes correlate well with the maximum historical extent of aquatic habitats mapped by Curtis Kruer in this same area (see Figure 18). Due to the poor resolution of the 1937 photographs specific changes in wetland areas near Gallatin Gateway could not be documented. The changes that have occurred appear to be due to agricultural activity and suburban development.

Analysis of the area near the East Gallatin River along Swamp Road also shows a significant reduction in riparian and wetland habitat. Figure 20 shows a view along the East Gallatin as seen on the 2001 CIR and the 1937 black and white scanned image. Much of the change appears to be associated with clearing of riparian vegetation, but several drainage ditches also appear on the 2001 imagery, suggesting that historic wetland areas have been drained. The name Swamp Road also hints at the past condition of this area. Even today the area is very wet, but the amount of riparian and wetland habitat has been reduced.

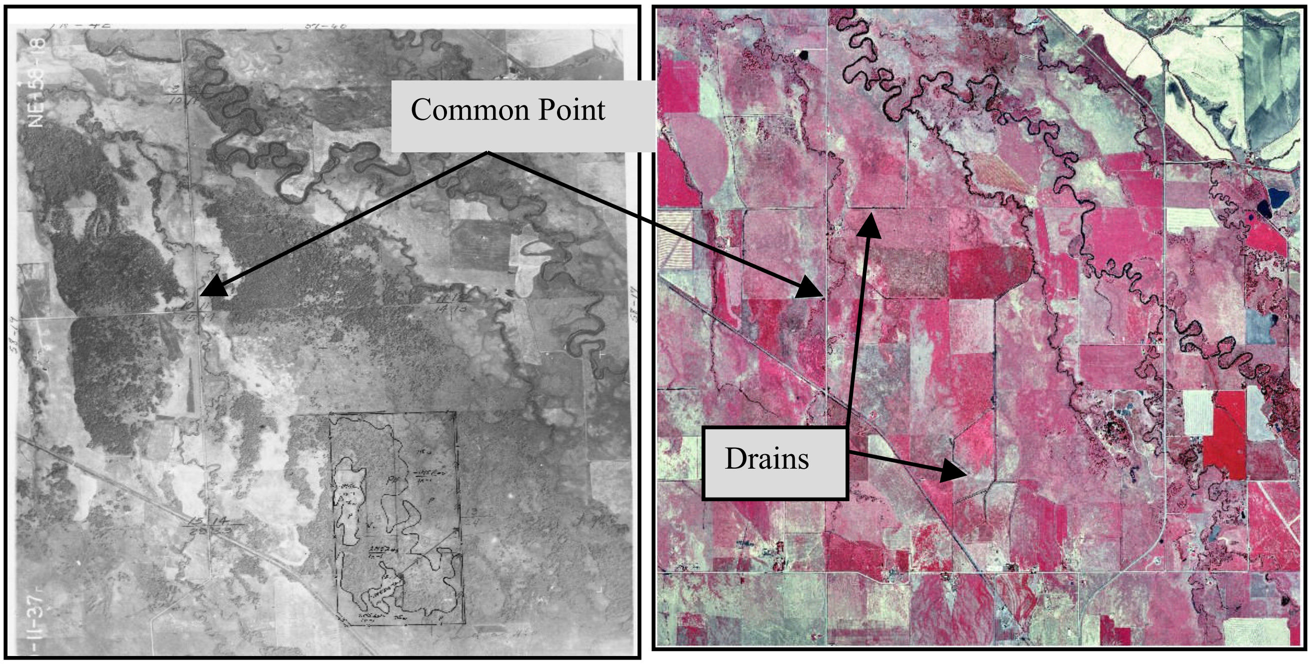

Figure 20. Comparison of 2001 CIR imagery and 1937 aerial photography near the East Gallatin River along Swamp Road (note that scales are not the same).

The final focus area analyzed, where Interstate 90 crosses the West Gallatin River, shows how construction of transportation corridors can impact riparian and wetland habitats. Figure 21 shows the 2001 CIR imagery and the scanned 1937 black and white imagery of the same area along Interstate 90. By 1937 the railroad bed had already been constructed. Surface water flow patterns appear altered from the south to the north of the railroad bed and has ponded along the south side of the railroad bed. During construction of the Interstate several gravel pits were excavated to the south of the Interstate. These gravel pits now form ponds that collect and concentrate surface water south of the Interstate. Both construction of the railroad bed and the Interstate appear to have resulted in a general drying of the land to the north of the Interstate and railroad. Several areas that appear wet on the 1937 image appear much dryer on the 2001 CIR image.

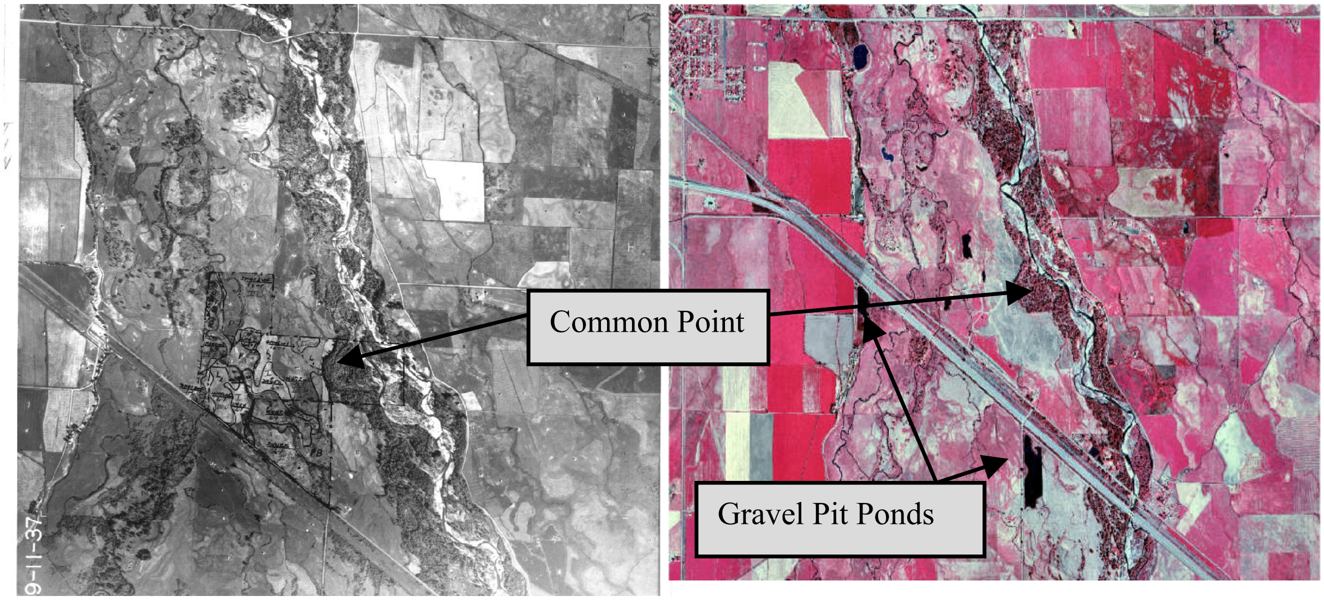

Figure 21. Comparison of 2001 CIR imagery and 1937 aerial photography near Manhattan, where Interstate 90 crosses the West Gallatin River (note that scales are not the same).

RECOMMENDATIONS FOR PRESERVATION AND RESTORATION

Regulatory Use of the Project Data

This project has compiled a significant amount of information on wetlands and riparian areas within the Gallatin Valley. While the scope of the project and the methods used did not allow for detailed analysis of these areas, it is hoped that the information will provide a solid starting point for more in-depth analysis. The information should be useful for regulatory management of these resources. The use of GIS software to compile the spatial data allows for easy editing in the future and the addition of more detailed data in the associated data tables as needed.

The information is intended to aid regulatory agencies and landuse planners with preservation and restoration of these important habitats. The results of the project have been or will be presented to the Gallatin County Planning Board, the Gallatin County Planning Department, Gallatin County Open Lands Board, City of Bozeman Planning Review Board, and Gallatin Conservation District Board. Both the Gallatin County and City of Bozeman GIS departments have been provided with the CIR Imagery and the GIS databases compiled for the project.

The intent is for interested agencies to use the project information to gain a better understanding of the current status and spatial distribution of wetlands and riparian areas. The GIS layers can be used during the review of proposed projects to see if wetland or riparian resources may be impacted. In these cases, the project data can act as a trigger for requiring a site-specific analysis.

Proposed changes to Gallatin County floodplain regulations include limitations on the clearing of riparian vegetation. The riparian/wetlands mixed layer along with the CIR basemap provide a good reference for documenting current conditions and reviewing proposed projects. The riparian/wetland mixed GIS layer and the CIR imagery can be used to document the location of woody riparian vegetation as of September 2001. Any clearing of woody riparian vegetation after September 2001 could be documented with future aerial photographs or field inspections.

Future Resource Analysis of Wetlands and Riparian Areas
This project provides a good baseline for the spatial distribution of wetland and riparian features in 2001 and can be used to compare with a future assessment of the spatial distribution of these features. An analysis of the land areas occupied by wetlands completed 20 years from now, along with the results of this project would show how much change has occurred and where it has occurred.

Functional Assessment of Wetlands
The project provides a good starting point for more detailed assessments of wetlands in the Gallatin Valley. The information compiled for this project could be used to direct efforts to complete functional assessments of wetlands and riparian areas in the Gallatin Valley. Possibilities include use by the Army Corp of Engineers to develop a Special Area Management Plan (SAMP). This type of work is currently being conducted in Yellowstone National Park. The Gallatin Local Water Quality District is currently considering working with the Montana Department of Environmental Quality (Randy Apfelbeck) and the Montana Natural Heritage Program to complete more detailed assessments of wetlands identified by this project. The methods used for this project and the results, may have value for developing procedures for mapping and monitoring wetlands statewide.

Wetland Protection and Restoration
The GIS data layers for *wetlands* and *riparian/wetlands mixed* provide a good reference for identifying wetland areas in the Gallatin Valley for preservation. Analysis of the project data shows that the northwestern portion of the valley contains a significant concentration of both wetland and riparian features. This area is supported by regional ground water discharge, which results in shallow water tables, stable water tables, and lots of springs and creeks. This ground water discharge area and the associated wetland features appears to be a fairly continuous ecosystem that has not been developed to a significant degree due to the presence of shallow ground water. Most of the changes that have occurred in this area are due to clearing of vegetation and installation of drains. Features in this area are good candidates for preservation. A number of wetlands in this area have been drained. These areas are good potential sites for restoration since the natural hydrology would support wetlands if the drains were removed.

Wetland features north of Bozeman along the East Gallatin River, south of Bozeman along Bozeman Creek, and east of Bozeman along Rocky Creek should also be targeted for preservation. As seen on Attachment D, historically these areas likely contained much more extensive wetland and riparian features. The areas shown in light blue on Attachment D show areas with potential for restoration projects.

CONCLUSIONS

Use of CIR Imagery and GIS Software to Inventory Wetland and Riparian Areas
Overall, the project was successful in using CIR imagery and GIS software to inventory wetland and riparian areas. However, it would take far more effort to attempt to delineate all the wetland areas identified, so detailed field work is still required to evaluate the wetlands identified by this project. The methods used allowed for completing an inventory of a 520 square mile area that is mostly private land without needing to obtain access to the land. Mapping these areas in the field and gaining access to all of the private land would have been time consuming, and many areas would have been inaccessible.

The steps taken to develop the high-resolution CIR imagery, including the lower altitude flight, scanning of the CIR film positives, use of a high-resolution photogrametric scanner, and the orthorectification software resulted in high quality imagery that could be used with GIS software as an image layer. It would have been difficult to analyze the images if the resolution was greater than 1 to 2 meters. Since the imagery was developed is has been used by many others for projects unrelated to this one due to the high qualtiy. The primary disadvantage of using the high-resolution imagery was the cost. It cost about $31,500 to develop the imagery, which is about $61/square mile. At this cost, using these methods to assess larger areas may be cost prohibitive.

While the CIR imagery did work well for this project, another method that could have been used would be to obtain multispectral digital image data and use computer software to classify wetland and riparian features. This type of approach may work better for large areas such as the entire state of Montana. More effort is required up front to develop the classifications, but once they are developed, large areas could be inventoried rapidly.

The use of GIS to compile the spatial data was effective. The GIS software allows for importing other existing spatial data such as soils, depth to ground water, or landuse layers into the project. It will also be easy to update and add to the GIS databases as more information on wetland and riparian areas is obtained.

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